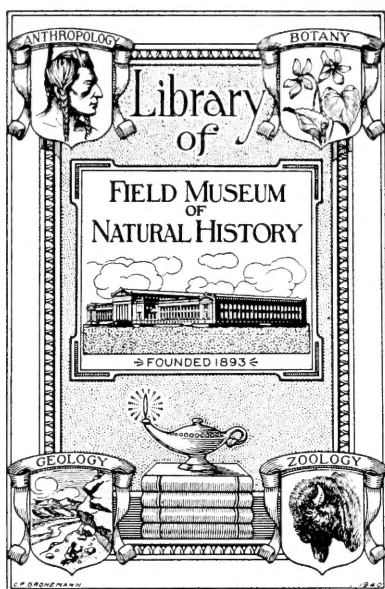


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BULLETIN OF THE UNIVERSITY OF TEXAS

No. 65.

ISSUED SEMI-MONTHLY

Scientific Series No. 77

July 1, 1905

OBSERVATIONS ON THE HABITS OF
SOME SOLITARY WASPS
OF TEXAS*

ILLUSTRATED WITH ORIGINAL PHOTOGRAPHS
TAKEN IN THE FIELD.

BY

CARL HARTMAN¹

*Read before the Texas Academy of Science, June 8, 1904

¹Contribution from the Zoological Laboratory of the University of Texas, No. 67



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Cultivated mind is the guardian genius of
democracy. . . . It is the only dictator
that freemen acknowledge and the only
security that freemen desire.

President Mirabeau B. Lamar.

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INTRODUCTION.

On morphological grounds wasps may be divided into two main groups, the Sphecina or digger-wasps, and the Vespina or true wasps, the latter of which have their wings folded in plaits when at rest. (Compare Figs. 1 and 2.) For the purpose of this paper, which is a study on habit, wasps may best be divided into the social and the solitary. This classification, based on habit, does not coincide with that based on the condition of the wings, for while the Sphecina are all solitary, the Vespina also include a large group of solitary wasps, the Eumenidae.

To render my account more complete, I shall briefly compare the habits of the social and the solitary wasps, transcribing from others.

A social community includes three castes: queens, drones, and workers. The queens alone survive the winter after mating with the drones, which, with the workers, perish of hunger and cold. In the spring the queen builds the first comb and rears the first lot of workers. These immediately take up the work of building the nest and feeding the young, while the queen devotes herself exclusively to egg-laying. Before long, many hundreds of workers are busy in the nest, and, late in the season, many queens and drones also appear, and the cycle of life is started anew.

The solitary wasps have only two sexes, the queens and the drones, and there is no division of labor, though some genera (*Pelopaeus*, *Bembex* and *Microbembex*) build their individual nests close together, forming colonies. There is a great diversity of habits both among the Eumenidae and the Sphecina. In either group the nests may be made of mud and attached, for shelter, under rocks, the eaves of buildings, or the hollows of trees, or they may be attached to the stems of plants. The nest may be tubes in the stems of plants, in boards or in the ground, either found ready made, or, as is usual, newly bored or dug by the individual wasps using them.

The adult wasps live on the nectar of flowers or on animal food, namely the same insect prey which they give their offspring. This usually consists in a given species of wasps of a particular kind of insect, one capturing only caterpillars, others only spiders, flies, bugs, beetles or other insects as the case may be.

The solitary wasps mate in the spring or summer. The female alone engages in the work of rearing the family. When the egg-laying time arrives, she digs or builds a nest, secures her prey, which she either kills outright or merely paralyzes, stores it in her nest and lays her eggs among the store of provisions. In most cases, the food is carried home once for all, the nest is closed over the egg and the mother flies away and digs a nest in another place, paying no further attention to the old nest. In a few genera, the mother maintains a further connection with her offspring, feeding the growing larva from day to day until it has spun its cocoon.

The egg of a solitary wasp hatches in one to three days into a maggot-like larva, which feeds on its store of provisions and grows for two weeks or less, when it spins its cocoon and becomes a pupa. In this state it remains two or three weeks in summer before emerging as the perfect insect; or if cold weather comes on, the insect remains quiescent in the pupal state until the following spring. It is probable that no adult solitary wasp survives the winter.

The solitary wasp emerges from its cocoon in possession of all the instincts of its ancestors. It is, moreover, born into the world alone, and there is no chance for imitation of its fellows, as is the case with social bees and wasps. Wonderful as these instincts are, they are not so perfect as was supposed, for observation has shown that they are to a high degree variable, and often show remarkable adaptation to circumstances, which is called by some, intelligence. The study of the habits of animals had been too little studied to bring out the fact of variability, for it is apparent that, to detect variations, be they in morphological characters or in actions, the type of structure or the normal action of the animals must first be determined. The present paper is a contribution in this direction, as it embodies observations of some twenty-eight species of Texas solitary wasps.

The principal students of the habits of solitary wasps, in fact, the only ones that have studied them comparatively, are M. J. H. Fabre of France and Mr. G. W. and Mrs. E. G. Peckham of Milwaukee, Wis. M. Fabre has given us the results of his keen and careful observations in his interesting and delightful papers, "*Souvenirs Entomologiques*." The Peckhams published their equally interesting results with sound deductions on the instincts of animals in "*Observations on the Instincts and Habits of Solitary Wasps*", Bulletin No. 2, Wisconsin Geological and Natural History Survey,

1898. It was this work which first induced me to take up the study of solitary wasps as a summer's recreative work and from which I have derived many helpful suggestions in my study. The remaining literature on the subject comprises short papers that record, for the most part, only individual observations.

Most of the observations recorded in the present paper were made in July, August and September of 1903. The work was not done continuously during this time, but in periods of from three to fourteen days, because of frequent interruptions, chiefly on account of rains, which were very heavy and long continued, drowning out many wasp larvae.

The scene of action of these exciting dramas of insect life was the sandy woods five miles southeast of Austin, on the high south bank of the Colorado River. The woods are a favorable place for studying solitary wasps, for they are numerous both in species and individuals and it is, moreover, easy to observe and to follow them because the sandy soil will support but a sparse vegetation, in which, in less favorable places, a wasp is often lost to view. In point of comfort to the observer, the woods offer a decided advantage, for, in the first place, he can often make use of the inviting shade of the spreading post-oak and hickory trees, though he often has to resort to his umbrella for protection against the burning rays of the sun. Wasps, it must be remembered, revel in hot, clear days and work best in the heat of noon-day when the mercury is flirting with the 100 mark. Indeed, on dreary days most of the wasps will not work at all, but will fly listlessly about, sipping nectar from the flowers. The second point of comfort is derived from the absence of "red bugs" and ticks. These pestiferous creatures are found on vegetation and since almost the only herbs found in the woods are grass-burs and bull-nettles, which one assiduously avoids anyhow, it follows that one collects few, if any, "red bugs" and ticks in the place in question.

The observations are recorded below by species and theoretical considerations have been intercolated wherever it was deemed necessary or desirable. These latter have been summed up in the "Conclusions" at the end.

I wish to take this opportunity of thanking Dr. S. Graenicher of Milwaukee and Dr. H. W. Ashmead of the Smithsonian for the identification of the Solitary and the Parasitic Wasps.

I. TWO EUMENIDAE.

(a) ODYNERUS DORSALIS, FABRE.

On September 2d, just before noon, I was walking through a cornfield and chanced upon a wasp that had just dropped clumsily on the ground between the blades of a clump of grass. I had, several days before, seen another individual of the same species drop down in a similar place and caught her without searching the premises. This time, however, having become more suspicious, I waited and watched. The wasp moved about slowly for a while, always looking at me with what seemed a stare, which was due to two yellow spots like eyes on the sides of her face. Gradually she walked further back; and as I stooped, I saw under the grass five neat mud cells. One of these was open and contained several small caterpillars (cotton-worms) already stored away. Soon the wasp flew away, presumably after more prey; I should have awaited her return and watched every step of the work of storing and building had not some digger wasps engaged my attention at the time. I therefore left the place before the wasp had returned. At 2:30 I went back to ascertain Mme. O.'s progress and found that the open cell had been closed with an out-turned saucer-shaped mud lid and that another cell had been begun. By 6:30 in the evening this was finished though still open and was occupied not by caterpillars, but by the wasp herself, which was lying inside and looking contentedly out. At 11:25 o'clock the next day the wasp must have been at work for several hours, for the cell had been nearly filled with caterpillars, which is the condition shown in Fig. 3. At 11:52, she came back carrying another caterpillar in her mandibles. I had pulled away some of the grass-blades above the nest and had my camera set up to take the picture of the nest. But this disconcerted her very little, and I was surprised at the ease with which she became accustomed to the change. After once flying away for a minute and circling about once or twice, she settled and placed the caterpillar in the nest. This was done in a peculiar manner. The wasp laid the caterpillar down at the opening of the cell and supported herself with her fore-feet on the edge. She then, with her mandibles, passed the caterpillar on as far as she could

reach, took a second hold and pushed it on further, repeating the operation until the whole length of the caterpillar was inside. Then she crawled up and with her head stuffed all the caterpillars as far back into the chamber as possible. This done, she cleaned her antennæ and flew away without seeming to take her bearings. She had evidently made so many trips to the spot that a study of the locality had become unnecessary.

By 7 p. m. the cell had been closed and another built, which the wasp was occupying for the night. A day's work with *dorsalis* evidently consisted of storing a cell, closing it, and building another to be used in the first instance as a lodging place for the night. Thus I found her still at home at 7:45 the next morning (September 4th), as shown in Fig. 4. She was lying in the cell, which her body comfortably filled, and was amusing herself with picking up unwary ants that chanced to pass too close to her threshold and, like the Harpies of old, grinding them in her jaws. I allowed her to store this cell, as well as build another; then I caught her and carried the cells home.

O. dorsalis. builds pretty mud-cells on the ground, choosing a place hidden from view by a clump of grass. The cells are broadly spindle-shaped, pointed at one end, which is left open until the cell is stored. The chambers do not touch each other for more of their length than is necessary for their mutual agglutination. This almost entire independence of the cells entails a considerable waste of building material as compared with the habit of *Pelopaeus cementarius*, which builds her cells side by side in rows and tiers of rows. It seems probable that the former method is the more primitive one, and that the latter has been superinduced by the mud-dauber's habit of building on flat surfaces. It is to be noticed that the lumen of a mud-dauber's cell still remains, in spite of the irregularity of the outer surface, cylindrical. The entire structure made by *dorsalis* is not only held together by the slight adhesion of the more or less fragile cells which compose it, but is also partially suspended by grass-roots imbedded in the plastered walls. The shape of this nest with the grass-roots attached can best be seen in the figures which are photographs taken at different stages in the construction. (Figs. 3, 4, 10, 11.)

The first wasplet emerged on October 7th, the others on October 8th, 9th, and 11th, respectively. One wasp failed to emerge and was probably from the fourth egg laid, and would normally have emerged on October 10th. If one cell was stored each day, the

first egg laid was on August 30, and the total period of development would be thirty-nine days. The wasps emerged (Fig. 11) by a small round opening gnawed in the cell wall. This hole was in three cases near the last sealed end, in one case at the opposite end.

One cell, the last one stored, I broke open to examine the condition of the caterpillars. I was especially anxious to see this, as I had once observed a specimen hang from a twig by one of the hind legs and chew the head of a cotton-worm, holding the caterpillar with her front and middle legs. I had often seen *Microbembex* do this in exactly the same way, and as this species feeds her larva on any insect, dry or fresh, or on any part of an insect in almost any condition, I concluded that she sucks as much of the insects' juices as she needs for her own sustenance and feeds the rest to the larva. Charles Janet has likewise observed this with *Vespa crabro*, where the workers, when the colony is threatened with over-population, kill some of the larvæ and pupæ, suck their juices and feed the remainder, rolled up in balls, to the surviving larvæ. In the case of *Odynerus*, I am pretty certain that she takes a caterpillar occasionally for her own delectation. I could draw quite near to the chewing individual and could see every movement, even of the mandibles, during the process. The condition of the caterpillars in the cell I opened, moreover, pointed to the fact that in chewing the caterpillar she was not preparing it for her offspring, but was satisfying her own hunger. Of the seven caterpillars found in the one cell, all were in good condition, and four responded very perceptibly to stimulation, one of the latter moving spontaneously. All remained in practically the same condition until attacked by the growing larva. (Fig. 10.)

I watched the growth of the larva until it was ready to spin its cocoon (September 26th). But as I had torn away a goodly part of the wall of the cell, it could not spin its cocoon all around and died. But the absence of the wall was not the chief cause of the pre-pupa's death. When I returned to her on October 7th, I found the pupal skin completely covered with egg cases of a parasite. On close examination, these proved to contain myriads of mites in various stages of development. Such egg-cases I have often noticed on dead digger-wasp larvæ, and they usually appear on the articulating membranes between the segments.

From cell No. 4 the imago failed to emerge. In November, when I broke open the cell, I found the nearly mature wasplet dead.

The cause of its death was easy to understand, as I found protruding from the sides of its abdomen a number of the egg-cases above mentioned.

As regards the length of developmental periods, the above data only give the total length of development as thirty-nine days and that of the egg and larva together twenty days.

(b) *ODYNERUS ARVENSIS*, SAUSS.

This species of *Odynerus* does not possess the architectural skill of its cousin just described. Its home is not such an elaborate domicile, built, as it were, for show as well as for use, but consists of any convenient crevice in a wall or fence-post. The nest is completed by closing the opening of the crevice with mud, much after the fashion of *Trypoxylon*. I have made a few observations on two nests of this *Odynerus*; those on the conditions of the caterpillars found in the nests are of particular interest. In general, the following facts do not justify Fabre's conclusions which he based on the habits of *O. reniformis*.

At noon, August 4th, a female *arvensis* was closing her nest in the niche of a brick wall. A few days before a *Trypoxylon* had emerged from the very niche now intended to be the cradle of another wasplet. I immediately opened the nest and drew out eight caterpillars, all of which were alive, six of them, in fact, so lively that they wriggled around in the small vial to which I had transferred them. I found no egg at first, but, looking carefully into the dark recess, I discovered the egg suspended from the ceiling of the little room. After breaking the suspensory thread with a knife and brushing the egg out, I placed it among the caterpillars in the bottom of the vial. Very few wasps' eggs could stand the rough handling which this egg received. The explanation of its endurance lies in the toughness of its shell. The larva hatched in two and one-half days, having shed a tough, translucent shell which could safely be handled with a pair of forceps. After fifteen hours the larva had attached itself to a writhing caterpillar and had grown perceptibly. The remaining data are as follows:

August 9. Five days after the nest was closed, two caterpillars have been devoured and the remaining six are still alive, of which four move spontaneously. The wasp larva is as large as one of the caterpillars. The larva takes a long rest this morning.

August 10, 6 p. m. All parts of all the caterpillars have been devoured.

August 11, 6 p. m. Larva nearly finished spinning cocoon.

August 29. Adult emerges.

Thus the length of the egg stage of *O. arvensis* is about two and a half days; of the larval stage, four and a half days; of the pupal stage, eighteen days.

Another nest which I observed an *arvensis* store and close on August 14th I opened nearly a month later (September 9th). I was expecting to see a wasp emerge by this time, and had placed a bottle over the entrance to receive it. I found in the nest no offspring of the wasp, but the red pupa of a fly and fourteen caterpillars, of which four had dried up, three were dead though in good condition and seven actually alive. The caterpillars' length of life is so striking that I deem it desirable to add the following table:

CONDITION OF CATERPILLARS.

Date.	Begun to shrink.	Dead but plump.	Alive.
September 9.....	4	3	7
September 14.....		5	5
September 19.....	5	1	4
September 26.....		2	3
September 29.....	3	1	1
October 11.....		1	

Thus three caterpillars lived 43 days, one 46 days and one remained, *for 58 days*, in a condition good enough to be added to any waspling's bill of fare.

A survey of these few facts would seem to indicate that, while the suspension of the egg and the young larva is a desirable condition and increases their chances of successful development, yet it is not an essential condition, as Fabre has contended. Nor is it essential, in consideration of the longevity of the paralyzed prey, that the caterpillars be devoured in the order in which they were stored.

II. AMMOPHILA PROCERA, DAHLB.

Ammophila is perhaps the most famous of all the digger wasps. Her homing faculty is most wonderful and is perhaps mainly responsible for the assumption of the sixth sense in insects, the sense of direction; the accuracy of her stinging instinct was long regarded as perfect. She has been several times observed to use a pebble as a tool with which to tamp the ground, so that a claim for her superior intelligence will not easily be contradicted. She is, moreover, a delightful subject for observation because of her tolerance of human company as well as her easy grace and her calm and dignified, though business-like ways.

In the course of the summer I was fortunate enough to observe six different individuals of *Am.* at work, four of which allowed me to witness the carrying home and storing of the caterpillars, while two individuals performed for me the whole process of digging, storing and closing up the nest, leaving me in the dark on only one step of the process, namely, the capture of the prey. All the individuals observed belonged to the species *procera*. It includes the most formidable members of the genus in America. The species is very variable in size. Five of the specimens whose acquaintance was made were among the largest; the sixth was much smaller and differed from the others in the number of caterpillars captured, as will be seen below. In the present description of *Ammophila's* habits, I shall follow the whole history of a nest from the beginning.

When *Ammophila* feels the necessity for doing so, she flies around in search of a suitable place to dig her nest. She is hard to satisfy in this respect, for I have seen her alight at a dozen different places and begin to dig before she finally decided on a place as good enough. To test the ground she does not waste time by digigng long at any one place, as does *Pompilus*, which often abandons six to eight half-finished nests before deciding on one to suit her; but *Ammophila* merely scratches the surface a little and, if dissatisfied, flies or runs off to another place. Some over-fastidious individuals have been known, however, to abandon the old nest and dig a new one near by after the former or even the ground around it had been slightly disturbed.

After the location has been chosen, *Ammophila* does not waste any more time deciding what to do next, but sets to work digging her nest, the tomb of her victim and the birthplace of her offspring. If the surface of the ground is dry and sandy, the hole is started by scratching out the sand with the front legs as is usual with most digger wasps. These use their front feet during the whole digging process, employing their mandibles only to bite loose the more solid earth or to break up the larger lumps. If the ground is hard at the surface, *Ammophila* begins by biting off pieces of earth and carrying them to one side, continuing this method until the nest is finished. The need of this mode of excavation as compared with the scratching method employed by most digger wasps becomes apparent when the shape of the nests are taken into consideration. The tunnel leading to the pocket of *Ammophila*'s nest is nearly vertical (Figs. 22 and 18), while the nest of other digger wasps is a nearly horizontal tube with a slight dilation at the end (Figs. 19 and 21). Fig. 6 represents *Ammophila* beginning her nest by biting the ground loose with her mandibles. Fig. 13 shows the nest farther advanced with the wasp already reaching down to bite off a "mouthful" of dirt. The work progresses rapidly, for *Ammophila* is a zealous and steady worker. Only now and then does she fly up and circle about a little to fix the locality of the nest in her mind. At first sixteen to eighteen loads of earth are carried out a minute, and as the nest deepens the time required for going in and out increases, so that as the nest nears completion, only eight to ten trips are made to the surface per minute. The wasp goes down the hole head first and backs out, turning around at the surface and running over to the dumping ground a few inches away. Here the load is flung down with a flirt accompanied by a joyful, enthusiastic buzz. After thus hurling away the lump of earth *Ammophila* gives a jump, turning suddenly face about, and goes back, half running, half flying, after another load. Fig. 22 shows the pile of sand carried out by the wasp on the left of the picture, i. e., on the side of the nest opposite the pocket towards which the entrance gallery slopes (at x).

The work of excavation occupies about thirty-five minutes in the loose soil of the woods where the observations were made. The completed nest, in general always characteristic of the species, varies somewhat with the individual and the condition of the soil in which it is dug. From above (Fig. 8) the nest appears as a perfectly round hole about half an inch in diameter leading nearly straight

down as far as one can see. Where the surface of the ground is soft and dry, the hole will be wide-mouthed like a funnel, due to the caving in of the sides.

On cross-sectioning the nest its true shape is revealed. The gallery, nearly vertical near the top, runs down in a gentle curve till it becomes nearly horizontal, where it widens out into a spacious pocket which received the caterpillar. Fig. 22 represents a nest of average size and typical shape. The distance from the mouth to the farthest end of the pocket is three inches; this is $\frac{3}{4}$ inch high and $1\frac{1}{2}$ inches from the surface of the ground and the tunnel is $\frac{3}{8}$ inch in diameter. The pile of excavated sand at the left is 3 inches from the entrance. Fig. 17 represents two smaller nests also dug by large individuals. The nests are of a different shape from the typical. Both have short tunnels; the pockets, one inch below the surface of the ground, have their long axes at right angles to the tunnels.

After the completion of the nest, the next problem confronting Mme. *Ammophila* is the procuring of a supply of food for her future offspring. Caterpillars always constitute the victim of the *Ammophilæ*, and the number varies with the species of the wasp and the size of the caterpillars. The large individuals of *procera* capture and store but one immense green "tomato" caterpillar, the subject of the photographs. The smaller store several small caterpillars of about the same length of their own body.

Before setting out on the chase, some species of *Ammophila* take the precaution of making a temporary closure of the nest, particularly if the provisioning is to be postponed to the next day, and the degree of care with which the closure is effected varies with the species and with the individual. A lump of earth may be laid over the entrance and this covered with a number of pellets so as to make the location indistinguishable. Another individual of *Ammophila urnaria* has been observed by the Peckhams to wedge a good sized stone deep into the neck of the burrow and then fill the space above, solidly, with smaller stones and earth. A third individual of the same specie neglected to close the nest at all. Fabre describes *Ammophila argentata* and *Ammophila sabulosa* as closing the nest immediately after it has been made, but *Ammophila holosericea* as leaving it open until it is completely stored. The last mentioned species stores five to six caterpillars, and Fabre thinks she leaves the nest open on account of the inconvenience of closing it so often. Dr. Williston, however,

has observed *Ammophila varrowi* take the greatest pains to close and conceal the entrance each time a caterpillar is brought in though she stores four to five of these. This is also the case with the smaller *procera* observed by me, for when she brought in the third caterpillar she scratched out much sand, bits of wood, etc., which she threw away. Finally she pulled out the plug at the bottom which she laid down close by for use at the final closure. The five larger specimens of *A. procera* observed by me agreed with the French *hirsuta* of Fabre, in that each stored but one large caterpillar and was thus relieved of the necessity of closing the nest. *Procera* differs from her French cousin in that she digs her nest before catching her prey as two to six hours elapse between the digging of the nest and the bringing home of the prey. It is thus seen that the habit of closing the nest while the wasp is off searching for her prey does not depend on the number or size of the caterpillars but seems to have developed independently and to different degrees in the different species and is by no means constant for any given species.

At 9:40 a. m. on July 22d, while busy observing the doings of *Monedula carolina* I saw a small *Ammophila* running over the sand carrying a good sized caterpillar in her mandibles. She soon dropped her victim and flew away, presumably to visit the nest and make sure of the road. In a few moments the wasp came back and searched right and left for the caterpillar. Twice she passed within two inches of it without noticing it, which would seem to indicate a rather weak sense of smell.

Again the caterpillar was picked up and carried off at the rate of five feet a minute over obstructions in the way, to her nest located in the shade of a clump of saplings. Here the caterpillar was laid down on a smooth surface several inches in diameter where the wasp began to open up its nest. Sand and dry twigs and leaves were pulled out and cast away promiscuously. The last piece of wood brought up was the largest and most compact and was not cast away like the others but was carefully laid down near the entrance. *Ammophila* did not forget the caterpillar during these few minutes but frequently approached and touched it with her antennae. When all was ready the wasp backed into the tunnel, got hold of the caterpillar and pulled it down. The caterpillar was sufficiently alive to grasp a blade of grass and hold on, but the wasp tugged till it had dragged the caterpillar into its grave.

After remaining inside three minutes, the wasp came out, walked

around a while and finally picked up the chip which it had taken out last and replaced it in the tunnel, reaching down as far as possible to press it in. This plug of wood probably served as a shelf to receive the bits of rubbish and the sand with which the tunnel was now being filled. Dry leaves and twigs were dropped into the hole and sand scratched in on top of these while all was stuffed down with the head. In eleven minutes the nest was filled and smoothed over. *Ammophila* then flew away and returned three times, remaining away eight minutes at a time. The nest which the mother wasp was soon to leave forever, seemed to have had a strange attraction for her. The last time she returned (at 10:27) she carried pieces of leaves and earth over the nest as if she wished to obliterate every trace of the work.

This small *Ammophila*, having to bring in three caterpillars, which necessitates making three hunting trips to store the nest, is, of course, benefited by closing up the nest each time before departing to keep out the flies and Mutillids bent on mischief. Her larger sisters are powerful enough to carry off the largest caterpillars; they therefore capture a single victim large enough to supply the larva and so have no need to close the nest while on the hunt, which may occupy from two to five hours.

It is a strange sight to see a large *Ammophila* carry her heavy burden home to the nest. The grass green caterpillar and the slender black wasp with her red metallic wings and abdomen girdled with bright red form a marked contrast to the grey sand over which they glide. It is a sight that never fails to excite one's interest to the utmost. One can not but admire the wasp for her immense strength and wonder that so small a creature can carry such a load. In spite of the disproportion between the wasp and the boat shaped burden, her rate of progress is rapid enough for she travels along at the rate of ten feet a minute over sticks, clumps of grass and inequalities of the surface. (Fig. 16.)

The most wonderful thing about *Ammophila*, however, is the almost unerring manner with which she finds her way back to the nest. Sometimes, it is true, she will drop her burden temporarily to fly away and assure herself that she is on the right road. But usually she will march on uninterruptedly in one general direction and come exactly to her nest in spite of the hundreds of crooks and turns around the various obstructions in her path.

Having arrived at the nest the caterpillar is laid down and the wasp goes inside to see that the way is clear and to determine

whether the tunnel is large enough to admit the caterpillar, for the wasp always, before pulling the caterpillar in, brings out a number of mouthfuls of earth and on each trip approaches the caterpillar as if to measure its thickness. Sometimes only a few, and sometimes many trips are made before the caterpillar is taken inside and it is usually a tight fit and requires considerable tugging on the part of the wasp.

Before the caterpillar is pulled in it is dragged over to the nest and laid down with its head nearest the entrance. Then the wasp backs down, grasps her prey with her mandibles and pulls it in. *Ammophila* usually remains inside five to six minutes to arrange the caterpillar and to lay the egg. Figs. 18 and 22 show the position of the egg (4 mm. in length) of one wasp which fixed it on the 10th segment from the head. The position varies anywhere from the 6th to 10th segment. The egg is always securely attached by one end (the head end of the embryo) to the side of the caterpillar and points with its free end towards the caterpillar's venter. When the larva hatches it occupies the same position that the egg did. It merely pierces the skin at the old point of attachment to suck the caterpillar's juices.

Ammophila now proceeds to close up the tunnel and leave her offspring to its fate. The tunnel is usually closed very carefully; some individuals are more or less careless, however, as were Nos. 72 and 73 whose nests are represented in Fig. 17. One nest was left open, the other was closed in a very perfunctory manner.

Ammophila searches in a radius of a yard and picks up large and small pieces and carries them to the nest (Fig. 8). If the piece is too large the wasp may carry it to the nest and try to fit it in or may discard it before she gets to the nest. She seems to have the power of judgment to a certain degree, for she evidently is able to determine whether a thing is too large to suit her use or not. Not only is debris thrown into the nest but the wasp alternates by scratching in the loose sand at the surface and tamping it down with her head. When the nest is full enough for the wasp to reach down comfortably she presses the separate pieces firmly down before she lets go and accompanies the strenuous operation with a cheerful buzz. Now it sometimes happens, especially towards the end of the operation, that a piece of wood is pressed down tightly, then pulled out and pressed down again and this repeated several times, so that one might suspect that the wasp were here improvising a tool with which to tamp down the sand. Indeed this very act was

observed by the Peckhams and Dr. Williston on *Ammophila urraria* and *Ammophila Yarrowi*. In each of these two cases the wasp used a pebble to tamp down and smoothe over the ground, not once merely, but several times, laying the pebble aside each time while she brushed on more sand. The use of the piece of wood by *Ammophila procera* in a similar manner is not so decisive since she presses a number of articles into the nearly closed entrance before she uses the last piece in any way approaching its use as a tool. Perhaps the use of the pebble by *A. Yarrowi*, the prairie species, is an extension of the more generalized habit of *procera* which lives in the woods where rubbish of all kinds is easily accessible and the whole tunnel is filled with it as shown in Fig. 18.

After the nest has been closed and the tunnel filled flush with the surface, sticks, whole leaves or blades of grass, etc. (things are not too large now), are carried over the nest to obliterate all traces of the wasp's work. In fact this is sometimes so skillfully done that unless one makes a mark he fails to find the nest again except by cutting vertical sections in the direction of the nest until this is opened.

The process of thus concealing the nest is, of course, highly protective to the human eye, though it can hardly be its real purpose to delude man or to entertain an admiring observer. The habit is probably a mere extension of the one which impels the wasp to carry debris into the tunnel to hold the sand which helps close the entrance.

The finishing touches having been applied, *Ammophila* is usually off and away immediately, though sometimes the fond mother seems unable to sever her connection with the nest so recently made and remains in the neighborhood visiting the nest occasionally to make a few changes. Once I caught a wasp in a neighboring tree after she had apparently finished her work; but she escaped through a hole in the net. For the next hour she continued to come near the nest again and again though she assiduously avoided me and my net. Gradually, however, she seemed to forget her experience and became so bold that I could approach close to her and easily captured this artist of her race.

Fig. 17 represents a section of the nests of wasps Nos. 72 and 73. It is a rare thing to observe two *Ammophilae* digging their nests so close together at the same time. Their behavior under these conditions seems to me to justify a special description of them here.

When on September 18th an *Ammophila* flew up in front of me, I knew from her actions that she had business interests in the neighborhood and so repaired to the inviting shade of a hickory tree to observe her. She settled and began to dig near an open *Ammophila* nest and I supposed that it belonged to her and that she was just closing it up. But she continued to dig another nest close by. Her work was not destined to go on smoothly, however, for hardly had five minutes passed, when a second individual (No. 73) came strutting along bearing a large green caterpillar. Wasp No. 72 remained ignorant of the approach of her sister until the latter came somersaulting over a stick at which the former was working. A fight ensued, the two clinching several times and even drawing their deadly weapons. They then flew away and No. 73 was the first to return. She took up her caterpillar, carried it to her nest, but returned to it, laid the caterpillar down, and proceeded to carry out sand as usual. At 2:02 No. 72 came back, while No. 73 was within her nest hidden from view, and was about to make off with the caterpillar which she found so handy. The rightful owner intercepted the thief, however, and in another duel, succeeded in recovering the purloined property. She then took the caterpillar up and carried it off for a distance of two feet, where she stopped to reconsider. It seems that the struggle for the recovery of the caterpillar must have reminded the wasp of the struggle to capture it, and that her next idea was to carry the caterpillar home, but she discovered her mistake in a moment. It certainly looked as though some such reflections were going on in the mind of the wasp. After hesitating a moment she turned around, carried the caterpillar back, laid it down at the entrance and hurriedly carried out only *one* mouthful of sand before dragging the caterpillar within. She then closed the nest in a slipshod manner and flew away at 2:23.

No. 72 returned and finished her nest without interruption where she had begun. By 6:45 she had not yet returned with her prey and I feared that she would not, since it was already very cool and since there were chances of her having been hurt in the struggle. She brought home a caterpillar, however, as I found one in the nest several days later, though she did neglect to close the nest. I found both caterpillars in good condition (Fig. 17) but without an egg. It is possible that in the duel the mature eggs, ready to be laid, were lost. Thus affairs sometimes go wrong even with the brilliant *Ammophilae*.

It is a significant fact *Ammophila* No. 72 picked up the stranger's caterpillar and walked away with it when she did. She had not yet dug the nest and therefore, according to Fabre, the instinct to procure her prey should not have yet manifested itself. This author experimented on *Sphex ichneumonea* which places her grasshopper at the entrance to her nest and then runs in and out again before dragging it down. He took advantage of a moment when the wasp was out of sight below to move the prey to a little distance, with the result that when the wasp came up, she brought her cricket to the same spot and left it as before, while she visited the interior of the nest. Since he repeated this experiment about forty times, and always with the same result, he concluded that nothing less than the performance of a certain series of acts in a certain order would satisfy her impulse. The Peckhams tried the same experiments and found the American *S. ichneumonae* would, after being fooled five or six times, carry the grasshopper inside in various ways but without first running down. It is thus apparent that wasps may perform certain instinctive acts though they be out of the usual routine, as was the case with my *Ammophila* which was about to procure the caterpillar before she had dug her nest.

The stinging habit of *Ammophila* and the resultant condition of the caterpillars have long been subjects of both the reason and the imagination among naturalists. I here append my own observations on the condition of the caterpillars. A discussion of the subject follows in the concluding chapter of this paper.

Notes on the condition of *Ammophila*'s caterpillars.

I. No. 16. July 22d, 9 a. m., three small caterpillars, all respond to stimulation.

July 23d, 6 p. m., caterpillar containing egg dead, others still alive.

II. No. 28. August 17th, caterpillar responds to stimulation at both ends of body.

August 20th, more lively than on August 17th.

August 23d, it is nearly dead.

III. No. 55. Egg laid 4:50 p. m., September 1st. Caterpillars move both ends of body spontaneously.

September 3d, caterpillar passed fœces twice and is more lively than the day before, moving front legs and posterior end of body spontaneously.

September 4th, 7 a. m., egg apparently hatched, larva occupying

same position as egg. 4 p. m., caterpillar has passed fœces again; will move only on stipulation; larva growing.

September 5th, 9:30, larva 6 mm. long, still occupying same position; caterpillar shrunken and nearly dead; can move head end on stimulation.

September 6th, a. m., larva nearly as long as caterpillar is wide. Sucking movements visible in larva.

September 8th, larva has sucked the skin of caterpillar dry and is devouring parts of this.

September 9th, caterpillar all eaten up except head and tail. Fig. 9 shows full grown wasp larva with a remnants of a devoured caterpillar together with a fresh caterpillar for comparison.

IV. No. 61, September 5th, caterpillar moves both ends slightly.

September 8th, egg dead. Caterpillar nearly dead; only extreme ends capable of slight movements on irritation.

V. No. 72. September 18th, first four and last three segments movable; has turned pink.

September 22d, head end responds to stimulation.

September 26th, posterior end jerks when pinched. Anterior end is shrinking.

September 27th, posterior end still alive, anterior end stiff.

VI. No. 73, September 18th. Head and last two segments move a little on stimulation.

September 22d. Several anterior segments respond to stimulation.

September 25th. Dead.

III. BEMBEX TEXANUS CR. AND MICROBEMBEX MONODONTA, SAY.

Microbembex and *Bembex* (Fig. 2) are both common in the sandy woods, where they often form large mixed colonies, building their nests side by side in great numbers. When a novice first comes upon one of these populous colonies on mid-day, when business is at its height, he is bewildered by the great number of wasps engaged in the general hubbub around the many holes that riddle the ground (Fig. 24). What confuses him more than anything else is the presence of the two kinds of wasps that look and act so much alike. Gradually, however, he becomes accustomed to the sight and soon begins to be able to distinguish easily the two species as they rest on the ground.

Microbembex monodonta is somewhat smaller and more slender than *Bembex Tex.* and the stripes across her abdomen are greenish yellow, while those of *Bembex* are yellowish blue. With practice one soon learns to distinguish the two species at a glance, by their actions as well as appearance. The manner of flight is characteristic in each case. *Bembex*, as she flies around, is always in a hurry, flying in a zigzag course and giving a buzz at each sudden turn like a blue-bottle fly. *Microbembex* is calmer in her movements, she never seems in a hurry but flies gracefully about like a bird skimming the water. Particularly on the hunt, as will be pointed out below, is the difference very marked. Often while digging in front of the nest the wasps will rise and leave their work for a moment, especially if disturbed by idlers flitting leisurely about. *Bembex Tex.* usually settles immediately to resume work, but *Microbembex* considers the interruption an opportunity to take a few moments of well-earned rest and bask a while in the sunlight.

Both of the species under consideration go through about the same actions in digging at their nests, the only difference being the quicker and more nervous ways of the smaller species. Here we notice the manner of digging in general characteristic of all the *Bembecids*. The body of the wasp, balanced, as it were, on the middle pair of legs, represents a teeter-totter in miniature. Each time the head goes down, the tail bobs up and a stream of

sand pours out from under the wasp, propelled by several smart strokes of the front legs in quick succession. Then there will follow a brief pause while the wasp rests with head in air as if looking around an instant to survey the landscape.

Activities in one of these *Bembecid* colonies does not begin until the rays of the sun have warmed the ground; and when the rays beat down from above, business is at its height and a gentle hum betokens the hustle and bustle of the inhabitants. When one visits the colony early in the forenoon, when scarcely a wasp is about, comparatively few of the nests are visible, since *Microbembex* closes up her nest from the outside and sleeps elsewhere, while occasionally a *Bembex Tex.* will have her nest closed from the inside. Towards ten o'clock, however, the doors are thrown open, one by one, and soon the actual population of the colony is manifested. On cloudy days, the wasps are not as busy, but lounge about, often resting for hours at the entrance and looking out upon the world.

Having thus located ourselves in the midst of this mixed colony, I shall follow *Microbembex* more closely and leave a detailed description of *Bembex texanus* for a time, when I shall have collected more data on this interesting wasp.

Microbembex is unique among the solitary wasps in the variety of the insects with which it feeds its larval offspring. *Bembex* takes several species of flies, but never anything but flies; similarly, a bug-catcher takes only bugs and a spider-ravisher only spiders. The greatest variety of the prey of the solitary wasps of which I can find any record is *Monedula punctata* described by Bates, who says that this species catches fire-beetles as well as flies. Our *Microbembex* will take home for provisioning its nest and insects that it finds already dead, or it will capture the living prey. On account of this great variety of food, I shall give a detailed list of the articles of food together with notes on the behavior of the wasps in capturing or in carrying home the prey.

(1) *Slender red caterpillars*, $1\frac{1}{4}$ inches long. I saw five of these carried home by different individuals. The caterpillar is carried home on the wing, though not directly, because of the weight of the burden, but in spurts. The wasp grasps her prey by its head with her mandibles and flies suddenly in a kind of jump to another point, one to three feet away, where she lays the caterpillar down and rests. Sometimes the wasp will fly off for a moment, leaving the caterpillar lying in the sand. When she re-

turns, to search for her prey, she does so by flying slowly round and round in the vicinity of the caterpillar.

These tactics expose the prey to considerable danger from parasitic flies. Indeed, I once noticed two grey Muscids with reddish abdomens follow a wasp with her caterpillar for a great distance. Their persistence greatly agitated *Microbembex*, and she several times left the caterpillar and pounced upon one or the other fly and threw it to the ground. The blow was, however, not serious, for the fly continued without fear as before. Why the wasp did not kill the interlopers on the spot, I can not understand. Fabre, as well as the Peckhams, wonder at the laxness of *Bembex* in her treatment of parasitic flies which she keeps driving away instead of killing them once for all. This would be easy for her to do, if she were so inclined; a single sting, applied as it is to another fly that is to serve as food, would forever rid her of one of these troublesome intruders. Both the French and the American observers fail to offer an explanation for the phenomenon. It may be that the sting is not used on other occasions than the capture of prey, just as is the case of the queen domestic bee the sting is never drawn except in mortal combat with a rival queen. Since it is always certain species of parasitic flies that are in attendance upon the wasps, it may be through mere familiarity with the flies, and the presence of those so near to the nest, that they are so much tolerated. For the flies are in every way treated like other wasps of the same species. I have seen a *Bembex* knock down another *Bembex* or a *Microbembex* and have even seen them clinch as if earnestly engaged in fighting, but they never drew their stings.

Notwithstanding the half hearted efforts of *Microbembex* to rid herself of her enemies, these follow her to her nest. Having arrived at the nest the wasp opens it, grasps the caterpillar with her hind legs and drags it inside, walking in head foremost. *Ammono-phila*, it will be remembered, backs into the nest and pulls her caterpillar in backwards.

(2) Another common object brought in by *Microbembex*, was the leg of a grasshopper. On several occasions I saw this carried along in the same way that the caterpillar was carried. Once an ant was making away with the leg of a grasshopper which it had probably purloined from the *Microbembex* herself. The wasp many times picked up the leg but the ant would not let go, but forced the wasp to drop it; until the latter gave up the fight.

(3) *Twelve small queens of ants.* These had been dead for some time. They all probably came from the same spot, as they were brought home in quick succession. The nest was left open while the queens were brought in, which is an exceptional thing for *Microbembex* to do.

(4) *Large red ant. (Pogonomyrmex Apache.)* I once saw a *Microbembex* pick up one of these fierce species and fly with it to a mesquit bush. There she hung from a twig by her front legs and held the ant with her other legs, while she bent her abdomen under her in her attempt to apply her long protruding sting. The ant seemed dead when I first saw the wasp pick it up and had probably been stung before; or the wasp may just have found the ant dead. That *Microbembex* does attack the living ants seems probable from a struggle I once saw between a wasp and two red ants, one of which had probably fastened its hold upon the wasp at the start until joined by the companion. The wasp was evidently dead when I took the two into a bottle with some sand. As I turned the bottle and so covered the insects with sand, the ants crawled to the surface and immediately began to dig down again to pull forth their dying adversary.

(5) *Flies* of various kinds, particularly Syrphids. On one occasion I noticed a wasp fly to a weed and hang there by one of her hind feet while with the remaining five she held an apparently dead Syrphid. I could approach very close to her and could see how she held the fly and alternately apply her mandibles and proboscis to the fly's thorax. It is probable that *Microbembex* was this time enjoying a little fly-juice for herself. Her action reminded me of *Odynerus dorsalis* which hung from a bush in the same manner and chewed a caterpillar, which she never does when this is intended for her larvae. Most solitary wasps suck the nectar of flowers for their sustenance.

While *Microbembex* was working on the fly, she several times dropped it and found it again without any trouble, knowing evidently that the fly was to be found on a plumb-line from where it was dropped. Once when the wind blew the fly out of the plumb-line, the wasp had some difficulty in finding it, as she persistently searched where the fly should have been. Thus spider-catchers have learned to find their spiders if these fall straight down from the place where they have been lodged.

(6) *Bugs* belonging to five or six different species and varying

from two to twelve mm. in length. Some of the bugs were perfectly dry, others were fresh when brought into the nest.

(7) *Small tree-hoppers, Tettigonia bifida, Say*, the species which form the sole prey of *Allyson melleus* and of *Rhopalum ab-dominale*.

(8) *Polistes rubiginosus*, so dry that it broke apart while *Microbembex* was carrying it.

(9) *Fresh grass-hopper*, which I killed and threw on the nesting-ground, was picked up by a *Microbembex*, as was also a dry Syrphid.

(10) Dry yellow Mutillid.

(11) *Old Orthopterous pupa-case* with dry dead pupa inside. Of all the things which *Microbembex* feeds to her larvae, these last two things are the toughest. The Mutillid must have been a most indigestible morsel, for the skeleton is so tough that in the fresh state it is very hard to drive a strong pin through it. The Mutillid was broken in two and the halves were carried off separately.

The above account gives one a very fair idea of the diet of larval *Microbembex*. It thus seems probable that the larval food consists mainly of insects, which the mother finds already dead and often dry. This is, moreover, borne out by the manner of the wasp's hunting, in which she differs decidedly from the solitary wasps and resembles markedly *Polistes* and *Vespa*. *Bembex* hunts her flies in a stormy fashion, flying around louder and faster than the prey she captures. *Microbembex* can be seen calmly flying through the woods much like a dragon fly, steadily maintaining a level of a foot from the ground. That she also attacks live insects is shown in that she attacks ants and in that her caterpillars are always limp and fresh. A fresh juicy caterpillar sandwiched in between a lot of old dry insects must indeed be a very welcome morsel for the growing larva.

It would thus seem that *Microbembex*, contenting herself with any insect she finds, has an advantage over *Bembex*, her nearest relative, and *Monedula*, both of which feed their larvae from day to day. But quantity alone does not bring the advantage. No doubt *Bembex*, knowing the habits of her prey, and having developed a skill in its capture (being a specialist in the art of fly-catching), can collect as much real nutritive substance as *Microbembex*. Though more generalized in the manner of procuring food, *Microbembex* has developed an improvement in her condition over *Bembex tex.* in that she

closes her nest before leaving it, often smoothing it over with considerable care. In this way she is spared the inroads that commensalistic larvae make into *Bembex's* store of food.

In their semi-social habit *Bembex* (and this would apply to *Microbembex*) has been regarded as transitional between the truly solitary and the social wasps. Both genera are more solitary than social for their only social trait consists in a tolerance of each other's presence in the immediate neighborhood. Beyond an occasional quarrel or the stealing of each other's flies the wasps preserve the peace of the colonies. This recalls by way of contrast the fierce combat of two *Ammophilae* which happened to dig their nests near each other. *Bembex* is furthermore said to show a social trait in the co-operation of the individuals in driving away parasitic flies. This is, however, more imaginary than real, for the fly is not killed nor is it driven away from the colony but merely from one individual's nest to another's.

Both *Bembex* and *Microbembex* are common species throughout the sandy woods. Every path or road or other area devoid of vegetation is occupied by individuals of these flourishing species. If an open spot is a favorable nesting place, wasps may congregate there in numbers sufficient to riddle the surface with holes, thus forming an extensive colony. Now, since such spots are not common, the thought suggested itself that the very numbers of the wasps forced them to occupy the same patch of ground, to dig their nests side by side, and thus by virtue of their familiarity with one another to live together in comparative peace. The tolerance of one another's presence would then be the first trace of the social instinct. The fact that the two different genera live together as peacefully as does *Bembex* with *Microbembex* seems to point to the same conclusion. Moreover, neither genus seems to show a marked predilection for living in the colony, for isolated individuals of both will be found throughout the woods, evidently as happy as when joining in the busy hum of a colony in the noon-day sun.

May it not even be that in this way numbers was the first stimulus toward social life as shown by a trace of it in *Bembex* and *Microbembex*?

IV. SOME FLY-CATCHERS.

(A.) MONEDULA CAROLINA, DRURY, THE BIG FLY CATCHER:

Monedula carolina is our largest digger-wasp with the exception of *Ammophila procera*. But the caterpillar-wasp looks comparatively weak, being slender, while the big fly-catcher has a most formidable appearance on account of her bulk and the warning yellow stripes of her abdomen. In the hot months of the year the wasp is often met with in search of prey or digging her nest in the sand, where she cuts a conspicuous figure. You cannot proceed far through the woods before one of the big fellows will come flying toward you with the loud threatening buzz of a bumble-bee. The wasp will fly around you to examine you on all sides, keeping her face turned toward you and as you advance, she will advance with you flying backward before you. This backward flight of *Monedula*, almost unique among insects, recalls the habit of the South African wasp, cited by the Peckhams, which is said to fly backward before a moving horse and catch the flies hovering over it. On the authority of a friend of mine, I can say the same for *Monedula*, which often followed his ox-team, picked off the flies and "buried" them in the ground. I have myself seen as many as three *carolinas* around a horse or cow at the same time and there can be no doubt that they do not hover around for curiosity's sake merely.

M. carolina spends three or four days digging her nest. The first two days she applies herself assiduously for hours at a time and will scrape out an astonishing pile of sand. Her working hours are, however, extremely irregular, especially on the third and fourth days. She may return to her nest at any time of the day, taking an hour or two for recreation in the midst of her work. I have seen her begin her nest in the morning before any digger-wasp was astir, work several hours with diligence and then close the nest and fly away, perhaps not to return again for work until late the next afternoon after *Bembex tex.* had retired or was playing hide and seek among the nests of her colony. *Carolina* is, moreover, least susceptible to the influences of the weather; for, while other digger-wasps will lie listlessly about on a cloudy day or sip nectar from the flowers, she may be as busy as ever.

Like the La Plata species, *Monedula punctata*, *Monedula carolina*

lays a single egg in the empty nest and waits for the larva to hatch before she begins to lay in a supply of flies. This explains her leisurely behavior on the third and fourth days of the nest, when she digs spasmodically or even visits the nest without working at all.

After the long and slender egg (six mm. in length) has hatched, the larva is kept well supplied with flies. These belong to any of the common species in the woods, *Musca domestica*, *Calliphora vomitoria* and especially the large *Volucella escurieus*, *Fabr. var. Mexicana*, *Macq.* She does not confine herself to a single species of fly as does *Thyreopus argus*, which preys on a species of *Dolichopus*. The size of the fly is not graduated to the size of the larva, as is said to be the case with *Bembex*, but it appears that the first fly met with, large or small, is captured and brought home. The wasp carries the fly with her middle pair of legs and on entering passes it deftly back to the last pair. This habit seems to be characteristic of the *Bembecids* in general.

The larva is fed for at least eleven days; I observed one individual continue this from Aug. 17th to Aug. 28th. During this time, twenty-four or more flies had been brought in, since, when I dug up the nest, I found the large larva, (which spun its cocoon the next day) surrounded by the remains of empty dipterous skeletons: 24 heads, 11 thoraces, 8 abdomens and many wings, the hardest parts of the different species of flies having been left. Fig 15 represents a pupa surrounded by the remains of flies in the sand.

M. carolina shows a remarkable variation in habit in that she sometimes closes her nest before she flies away, sometimes leaves it open and this applies to some individuals as well as to the species as a whole. Of the eleven specimens that I observed, six closed the nest carefully each time they left it; two always left theirs open; two closed theirs once or twice in a slipshod manner leaving it open at all other times; and one closed hers carefully until she begun to carry in flies, when it was never again closed until the larva was full grown.

Each individual performs the final closure with scrupulous care, the whole tunnel being filled with sand and the surface smoothed over in the radius of a foot. One wasp kept returning to the nest occasionally for several days to throw more sand over the entrance to her old nest until she had kicked up a pile of sand three inches deep.

Monedula's nest is the largest digger-wasp nest I know. The entrance, seen from above, has the form of an arch which measures about an inch across the base and three-fourths of an inch in height. Fig. 7 shows the wasp just crawling forth from her nest. The nest is a cylindrical tube more or less bent. It is three to five-eighths of an inch in diameter and runs down in a gentle slope for eighteen inches to a slight dilatation, the chamber, nine or ten inches below the surface. Fig. 21 is a photograph of a nest in section. It shows at about its middle point a rather abrupt turn to the left.

If the nest has been closed, *Monedula* opens it without dropping her prey which she may happen to be carrying home. If the fly is accidentally dropped it is always discarded, even carried off to a distance and flung away.

This fly-catcher, like the other fly-catchers of the family, stings to kill its victim. Every fly that I examined was dead, even those just brought home and dropped before the entrance.

(B.) NOTES ON THE STINGING HABITS OF *TACHYSPTX TEXANUS*,
CR., *BEMBEX TEXANUS*, *CR.* AND *NOTOGLOSSA*
(*OXYBELUS*) *AMERICANA*, ROB.

It has been supposed of a number of fly-catchers that they pounce upon their victim in mid-air. This seems to have been the case with a specimen of *T. texanus* that come under my observation. I was busy working in the sand when I heard a light buzz at my right. *Tachysptx* was inflicting the death-sting on a fly of the domestic species, much larger than herself, and the two had dropped to the ground from above. Possibly the fly had been attacked while resting on a branch of a near-by tree but circumstances pointed rather to the conclusion that the struggle had begun with both on the wing. The fly lay helpless on its back and the wasp lay across the fly's thorax curled around the left side with her sting fixed in the fly's sternum. I placed the tow in a collecting-bottle with some sand. For two minutes the wasp held the fly impaled on her sting while she spent some time washing her face and antennae. She also walked around in the bottle, still carrying the fly, until she discovered that she was imprisoned, when she dropped her victim and flew excitedly around.

This observation recalls Fabre's assertion that *Oxybelus* carries home the flies impaled on the sting. The Peckhams, however, found that the wasp holds the fly with her hind legs and allows it to pro-

trude so far beyond the abdomen as to give it the appearance of being attached to the sting.

About the noon hour on a hot, sunny day, when the impulse to hunt is at its height, *Bembex* can be seen following her favorite occupation. One would suppose that where flies are most plentiful there the wasp would most often be seen. And this is found to be a fact. The hunting and stinging habit of *Bembex* may readily be observed by watching a pile of horse-droppings near a *Bembex* colony. Flies collect and a wasp soon comes along to collect flies. She buzzes furiously about and the timid flies instinctively creep away as if to hide from their hereditary mortal enemy. The wasp makes a dozen or more circuits in the wildest zig-zag fashion darting again and again at flies on the dung-heap. Flights of this kind alternate with periods of rest on the sand near by, where the wasp stops to wash her face and smooth her wings while the motion of her abdomen betokens the rapid breathing occasioned by the strenuous exercise. After a number of trials, usually many, *Bembex* succeeds in pouncing on a fly. Quick as a flash the wasp is off for her nest with her victim. The operation is performed so quickly that it is utterly impossible to determine how the fly is captured and stung. I therefore captured a fly and pinned it down. *Bembex* returned, took hold of the fly with her legs and at the same time arched her abdomen under and stung the fly on the under surface of the thorax. The fly failing to yield to her efforts, the wasp immediately rose, caught sight of another fly and succeeded in capturing it. After a few moments she was back and attacked my fly as before. I then removed the pin. The wasp took up the dead fly four times, rejecting it each time after having risen several feet in the air. It did not take her long to find out that there was something wrong with her capture.

A wasp will return to the same hunting grounds until her larder is filled for the day. I have seen one wasp carry off as many as eight flies in quick succession. A number of times, too, I have amused myself by allowing a wasp to take a dead fly from my hand, so that I could feel the active little creature as well as observe its every movement. Two wasps of a species cannot agree to hunt together at the same place—they will quarrel in angry tones until one will withdraw and priority seems, in vespine races, to be the claim usually recognized.

But the tiny black *Notoglossa* with her red-tipped abdomen will

pay no attention to the big *Bembex* buzzing about. Though scarcely a quarter of an inch in length she hunts much like her comparatively gigantic congener. Her prey consists of gnats and other very small flies which she catches with greater facility than *Bembex* catches her prey. I have seen *Notoglossa texanus* rest on horses' feet and "loaf around" for hours, apparently on the lookout for her quarry. On one occasion I saw a tiny wasp appear repeatedly among a swarm of gnats that had gathered around a sore on my horse's ear.

V. THE BUG-HUNTERS.

(a) BEMBEX BELFRAGEI, CR., THE BIG BUG-HUNTER.

Four times during the season I had the pleasure of observing individuals of this interesting species at work. The species is rather a common one, and I should have observed more individuals had I had time. She is enjoyable company, for she does not object to one being near her. Her prey, however, I should think, might consist of a more inviting kind than the bug she captures, being stink-bugs at that.

B. belfragei is one of the first solitary wasps I saw in the field and is chiefly responsible for inducing me to spend several weeks among them. I came upon the first specimen on July 16th at 9:12 o'clock a. m. digging her nest in a wagon track. She had already made considerable progress in her work, for she seemed to bring the sand from some depth. She would remain out of sight for thirty to fifty seconds, then push up a load of sand and kick it out of the entrance. Fifteen to twenty seconds she would spend on the surface scattering the sand away from the entrance, as is more extensively the habit of *Bembex tex.* and *Monedula carolina*. When at work digging *B. belfragei* cuts about the same figure as *B. texanus* described above. The tibiae and tarsi of the front legs with their long spines are used to scratch the sand and throw it back under the wasp's body. Each time the head goes down, a single stroke of the leg is given and not several, as is the case with *Bembex texanus*.

Once a Mutilled, five or six species of which are common in the woods, came running along the wagon-track, looked into the nest and greatly excited the owner, for the latter flew up with an angry buzz, darted at the intruder and put her to flight.

At 11:40 the wasp began to interrupt her work by rising into the air, circling several times, settling some distance from the nest and then returning to work. She repeated this three or four times; finally at 11:47 she came up from her nest, headforemost, instead of backwards, with sand, as she had been doing. She then closed up the entrance by scratching in sand until the entrance was covered flush with the surface and then flew away. After an absence of twenty-eight minutes, she returned and entered the nest without my seeing

it, remained inside one minute and came out, closing the nest as before. This time she flew off without first circling about the nest.

While the wasp was gone on the second hunting trip, a large Mutilled again came along, scratching at a great many places, here and there. Thus also she removed the sand from the entrance of the wasp's nest, though she did not enter, but merely looked in and passed on.

At 11:33 the wasp came back again with a large gray bug, alighting with it just in front of the entrance. I expected her to show some agitation at the disturbance made at her nest by the Mutilled; she appeared not to notice it, however, but holding the large bug with her middle pair of legs and balancing herself on her hind pair, she dug away some sand with her front pair. She then dropped the bug and crawled over it into the burrow. In a few moments she came up, head foremost, grasped the bug by an antenna with her mandible and drew him inside. In one and one-half minutes, she came out again, closed her nest carefully and flew away.

During the afternoon *belfragei* came home without a bug. A wagon had just come along and unfortunately cut away several inches of the burrow. Such a widespread disturbance in front of the nest would drive an ordinary wasp out of her wits. But this level-headed bug-catcher seemed, in spite of it, to know just where her nest was located and went to work clearing away the sand that had caved in. As she progressed, more and more sand fell from above and I assisted her by making an arch-way above with a piece of white paste-board to hold up the sand. Soon she had the nest open again and at 4:33 she flew away, this time leaving the nest open.

At 8:25 on the following morning, wagon-wheels had again covered up all the trace of the nest and *belfragei* was again in a quandary. Believing that she could not find her nest this time, I proceeded to find it for her by cutting off slices of sand with a hoe in the direction of the nest until I came upon the tunnel four inches from the original entrance. All the time the wasp remained near the hoe like a playful kitten,—a remarkable performance for a wasp. She flew away before I had quite finished but returned in three minutes and went straight into the hole which I had prepared for her, resuming her work as though nothing had happened.

At 8:42 the wasp flew away leaving the hole open. At 10:55 she had been back with a bug, which she took in as before, and had flown away after closing the nest behind her. This was the last

I saw of her. On July 21st, I returned to dig up the nest but failed to trace it.

The individual whose actions were just described (No. 39) was the least sensitive to my presence of all the wasps I have known. Once I took her up in a bottle, and as soon as released she went on the even tenor of her ways. Other specimens I observed, while not annoyed at my presence, resented any movement on my part. They differed rather markedly also in the manner of their approach to the nest and of carrying their prey.

My second example of *B. belfragei* having dug the nest completely in the forenoon, carried into it four bugs from 1:42 to 4:10. Holding the bug venter uppermost with her middle pair of legs, the wasp would settle upon the sand that closed the entrance and stop there for nearly a minute in a listening attitude. Perhaps she was getting her breath after the long flight with her burden, for her abdomen would heave up and down after the manner insects have of breathing. At any rate, the delay in getting the bug under cover must be disadvantageous to the species for the reason that it gives parasitic or commensalistic flies more time to smell the bugs and find the nest. The habit is widespread within the species, for nearly all the individuals I saw act in this way. This hesitation at the entrance forms a striking contrast to the habit of *Rhopalum* which dives into her open doorway.

Assured that all is well, *belfragei* opens up the nest with her front legs, still holding the bug with her middle pair, and walks in. When just inside, she passes the bug back to the third pair of legs, or, dropping it, she advances until she can conveniently grasp it with the third pair. Then she picks it up again and passes on, the bug now projecting beyond the tip of the wasp's abdomen.

At 4:10 p. m. the last bug was brought in and the wasp began to permanently close the nest. After remaining inside for seven minutes, she came forth scratching the sand back to fill up the tunnel, biting it loose from the sides, pulling it from the surface and pressing it down with her abdomen. I caught her when she had nearly finished, and opened the nest. The tunnel, three-eighths of an inch in diameter and ten inches long, was entirely filled with sand and could be traced only by virtue of the dryness and the light color of the sand stuffed in. The pocket was one inch long and five-eighths inch in diameter and was five inches below the surface of the ground. It contained seven bugs. The egg was attached to the mesosternum

of the bug and was directed forward so that it extended for a distance along the proboscis (Fig. 14.)

The bugs taken from the nest were all of the family of *Lygaeidae*. Of the seven, three kicked violently when touched and the remainder showed some signs of life. After a day and a half three bugs were still alive, while the other four had just died. The former lived at least half a day longer. On Aug. 28th three large fly-maggots (Muscids) were crawling around the sand in the bottle as if trying to get out. The egg had disappeared.

My third specimen (No. 46) came swooping down from the tree tops with her heavy burden. I have never seen the species out on the hunt, probably because she hunts altogether among the trees, the home of her prey. Each time No. 46 came home with a bug she descended out of the tree that overshadowed the nest. She carried in five bugs in two and a half hours, completing her labors at 7:00 p. m., when she closed the nest. The nest was probably dug and provisioned on the same day (Aug. 27th), as was that of No. 39, judging from the late hour at which the bugs were caught. I failed to trace the tunnel this time but came upon the chamber containing the bugs, which were all broad, gray ones of the genus *Cryptomenus*, excepting one, a slender purplish bug belonging to the *Lygaeidae*. This latter was the first brought in and contained the egg which was attached in the identical manner as that of No. 39. If the egg was laid just after this first bug was carried in the length of the egg stage of this species is forty-one hours. The larva died after three days. Three bugs lived two days; the other two were brought in dead. These bugs and the wasp's egg are shown in Fig. 14.

The fourth and last specimen on which I have notes finished digging her nest by 10:12, Aug. 31. As was the case with No. 1, she made a series of locality studies in preparation for her first departure by walking around on the sand in the neighborhood of her nest. At 10:12 she closed up the entrance carefully and flew away. At 1:00 o'clock I returned to the nest, which was closed. At 1:27 the wasp returned, coming down out of the neighboring trees. She did not descend in a sudden continuous swoop, but in gentle jerks as if she were descending a flight of stairs and had to pause at each step to adjust her load. This jerky motion goes on until she hovers over a bush two feet high standing between the wasp and the nest. Then she takes a sudden dive through an opening between the branches of

the bush and lands on her nest. This strange mode of approach was used each time a bug was brought home, at 1:27, 2:17, 3:27, 4:41. It thus required over an hour for this individual to catch a bug as against one-half hour for the others.

The chamber of this nest, which was closed like the others, was about the same dimensions as noted for the nest of No. 39. It contained five bugs, one of which was dead, three nearly dead and one so little paralyzed that it kicked spontaneously. Three of the bugs lived one day, while the lively one lived for five days.

The egg had the conventional position on the sternum of a bug, but it was soon lost. A Muscid larva pupated on Sept. 3d and some Phorid pupae were also present in the bottle on Sept. 15th.

It is thus seen that *Bembex belfragei* displays a considerable amount of individual variation in general disposition, in the manner of approaching and leaving the nest, in the time required to dig and store it. The effect of her sting is also variable, the victim being killed outright or living as long as five days. It may be said that this wasp is a novice in the art of stinging her prey, though she shows considerable more skill than *Bembex texanus* or *Monedula carolina*.

(b) BEMBIDULA PARATA, PROV., AND BEMBIDULA PICTIFRONS,
SMITH.

Of these interesting and rather common species my notes show observations on only four individuals. From a study of their habits I concluded that I was dealing with a single species. However, No. 58 below was identified for me as *B. parata* and No. 48 as *pictifrons*; of the others I am in doubt. Since the habits of the two species agree so closely, I shall describe them as if they were really a single species. The wasps are smaller and stouter than *Bembex belfragei*, big bug-catcher, and the yellow bands on the abdomen and thorax are comparatively broader and more intensely yellow than those of the latter, so that as the wasps fly around the impression of yellow is the predominating one over that of black, the predominating color of *belfragei*.

Specimen No. 58 I observed from the time she was flying around in search of a suitable place to dig her nest up to the final closing. The wasp began digging at several places and finally chose the side of a shallow pit where only the day before I had dug up an *Ammophila* nest. The pit was six inches deep and the nest was begun three inches below the upper edge of one side.

Bembidula digs much like the other members of her family already described: *Bembex*, *Microbembex* and *Monedula*. During the progress of the work of digging the wasp makes short excursions, (on foot chiefly), around the neighborhood. Wasp No. 58 continued digging for about two hours and at 12:30, when she had finished, she closed the entrance with sand. Before venturing away from her nest for the first time, she made a rather careful study of the locality, flying in and out among the herbs and bushes. In closing her nest, No. 58 had more difficulty than her sisters because her nest opened on a sloping surface like a cave on the face of a precipice. In other cases, where the nest ran down from a level surface, there was left after closing a shallow elliptical depression like a gentle finger imprint almost characteristic of the species. I frequently made use of this depression to tell whether or not a wasp had visited her nest during my absence: I would smooth the entrance over and if the pit was visible on my return I had reason to believe that the wasp had come and gone. Bembecids as a rule are not easily disturbed by changes around their nests, as is the case with the Pompilidae to a high degree. In the case of the species under consideration, I often smoothed over the sand covering the entrance, but this in no way, as far as I could detect, disconcerted the wasp on her return. Sometimes I would, in addition, lay a blade of grass over the nest. The wasp would nevertheless find the nest immediately and merely kick the obstruction away. One individual, with a temper, once picked it up with her mandibles, carried it off to a distance and flung it angrily away.

At 12:30 the nest of wasp No. 58, which I began to describe, was completed and the wasp had flown away. I was at the time trying to keep four nests of three different species under observation and therefore failed to see this one enter her nest on her first return.

At 3:07 she came back again and descended slowly toward the nest. When within three inches of the surface, she hovered an instant, then dropped suddenly like a dead-weight and after a moment's pause at the entrance opened it up and walked in. As she entered I could see her pass a very small bug back to her hind legs in so deft a manner as would do credit to a slight-of-hand performer. She remained inside but a minute, then came out, closing the nest behind her. In every case that came under my observation this species closed the nest thoroughly before flying away. On her re-

turn she approaches cautiously and, when just over the nest, drops suddenly upon it. Moreover, she always carries the bug with her middle pair of legs and passes it back to the third pair on entering.

At 3:39, the wasp was back again. Her manner of approach this time was quite different than before. Instead of flying directly down toward the nest, she flew back and forth above it in nearly parallel lines like a pendulum with ever shortening oscillations. This manner of approach she employed nearly every time. Other individuals of the species showed a habit approaching this, though not so marked.

At 4:31, No. 58 came back again, but not straight to the nest. She flew around from bush to bush in the vicinity, hanging from the twigs a minute at a time. Once she allowed me to come close enough to see distinctly that she was hanging upside down by her first and third pairs of legs, while with her middle pair she clasped a small bug, holding it by its interior end, head directed forward. After thus "hanging around" for some minutes, she returned to the nest after her wonted manner.

The next two days, Sept. 4th and 5th, were also spent in procuring provisions. The nights were not spent in the nest; this was carefully closed at the last departure in the afternoon and the night was spent in other parts. I have seen the species late in the evening dig a shallow nest and crawl into it for the night, closing it from the inside.

At 5:33 the wasp brought in her last bug. It was fourteen minutes this time before she again made her appearance for the reason that she was now making the permanent closure of the nest after the manner of *Bembex belfragei*. After the burrow was filled with sand she scratched the sand all around the nest, even climbing to the top of the bank three inches above pulling down the sand. In this way all trace of the nest was obliterated. I immediately dug up the nest. Eighteen bugs were found in the lower, somewhat dilated end. There was no wasp egg or larva but three large fly-maggots were busy eating the store of food.

Specimen No. 48 began digging her nest at 9:15 a. m., Aug. 31st and finished at 10:55. She, too, made an extensive locality study among the weeds in the vicinity, returning to the nest several times before flying away. She stored five bugs the first day. A parasitic fly, *Masiene sp.*, kept hovering around the nest and twice, when the wasp returned with a bug, the fly flew up four feet or more to meet

the wasp and as the latter descended, gradually the fly flew backward ahead of the wasp, maintaining a distance of about three inches from her until the two reached the nest. After this was opened and the wasp had entered, the fly went in also and came out just ahead of the wasp. In the nest I found five bugs, one of which held the egg which was attached exactly like the egg of *B. belfragei*.

No. 50 began digging her nest at 9:30, only five feet from that of No. 48, also on the same day. She stored her bugs in the afternoon of September 2nd. As the wasp had not visited the nest after 11:20 Sept. 2nd, I opened the nest at 8:00 a. m. Sept. 3rd and found a large larva among ten bugs, the viscera of most of which had already been eaten away. The nest is shown in Fig. 19. It was a compound curve sloping downward and toward the right for a distance of eight inches. The pocket, four and one-half inches from the surface, was one-half inch in diameter and three-fourth inch in length.

The larva began spinning its cocoon at 10:00 a. m. Sept. 5, i. e. on the fifth day after the egg was laid. It never quite finished spinning, though the pupa lived for ten days.

(c) HOPLISOIDES, SP?

This is a little brown wasp with yellow stripes, inconspicuous on account of its small size but of very energetic and business-like airs—like certain under-sized people. The species is rather rare, as I have seen only several specimens and but one actually at work on her nest. While I was standing in the shade, awaiting the return of several bug-catchers that had gone hunting, a *Hoplisoides* dropped down in front of me. She was carrying something which she let fall and immediately began digging for the entrance to her nest. She had evidently lost trace of this, for she dug at a number of places in vain. Bits of dried leaves and bark were strewn about and these were kicked away as though they were the cause of the wasp's mistake, instead of being fit land-marks by which the wasp might have been guided and the mistake prevented. As it was, some minutes were spent in finding and opening the nest. When this was done the wasp walked in. Assured that all was right, she came out and seized a piece of wood of the size and shape of the bug she had brought, rose on the wing to the height of a few inches, settled at the entrance again and walked in. I expected her to take in the bug lying in the entrance; but the piece of wood was carried in first

and this I afterwards found in the chamber among the bugs of the wasp's collection. She came out after this delay of a few minutes, seized the bug, rose on the wing after the usual manner, settled at the entrance and walked in with the bug, holding it under her abdomen with her middle legs. When only half inside the bug was dropped while the wasp crawled inside over it. After $\frac{1}{4}$ minute the bug was pulled inside from within, as is occasionally done by *Bembidula*. In one-half minute the wasp came out, closed the nest and after making a few detours at the height of three to four feet, flew away.

At 4:10 she came back again with another bug. This time also she encountered some difficulties in finding the entrance though there were many sticks and leaves about to guide her to the exact spot. *Bembex* or *Microbembex* or *Ammophila* never has so much trouble in getting into her nest even when there are no well recognized land-marks present to guide her. But instead of "making haste slowly," this wasp loses time and energy in the hurry. She immediately begins to dig for the entrance after having dropped the bug, unlike *Bembex*, which continues to keep hold on the fly for some time while digging. After the nest has been opened, the bug is taken in exactly as before. In a minute the wasp comes out again backwards, scratching out sand, possibly some that had caved in. Finally she comes out head first scratching out sand, closing the entrance imperfectly, and flies away. By 4:51 she had come back again and was busy excavating the nest, scratching the sand with her forefeet and pushing it out with her abdomen. In this way she soon closed the entrance from within and remained inside one minute. At her appearance this time, she came out head foremost, scratching in sand as she came, after the fashion of the larger bug-catchers above described, when they are ready to close up the nest and leave it. This I supposed *Hoplisoides* to be doing in this instance and my suspicion proved to be wellfounded, because, when the nest was nearly filled with sand, the wasp began to carry into it bits of debris, that lay scattered about continuing at the same time to scratch in sand on top of them, like *Ammophila* is wont to do. While busy on the surface *Hoplisoides* holds her wings extended out obliquely like the social wasps. When held at a certain angle to the sun's rays, the wings have a metallic blue lustre.

Convinced that the work on the nest was nearing completion I caught the wasp and immediately dug up the nest and came upon

the chamber three-eighths inches in diameter and one-half inch long, five inches from the entrance and two and one-half inches below the surface of the soil. The passage from the entrance to the chamber was filled with sand and could be traced only near the ends.

The chambers contained seven bugs, among which lay the above mentioned piece of wood as though the wasp had carried it in, supposing it to be a bug. The bugs were all nymphs of the same species, one of the family *Membracidae*. Three of the bugs responded to stimulation. The egg, 2 mm. in length was attached to the ventral surface of the bug close to and parallel to the margin of the thorax opposite the first and second pairs of legs. From its position I supposed this bug to be one of the last brought in.

On September 4th, two days later two bugs responded to stimulation by a slight twitching. The egg looked dead on this day and finally withered.

(d) *ALYSON MELLEUS*, SAY.

A. melleus is a slender wasp, less than half an inch long, in shape and size much like *Agencia*, the little spider-ravisher. Black is the predominating color of her body, her head, antennae, tip of wings, and abdomen having that color, while her thorax and wings are red. She is, moreover, easily recognized by the pair of round white spots on the sides of her abdomen. She resembles the *Agencia* mentioned also in the easy grace with which she flits from place to place when on the hunt, which is mostly done on herbs and bushes. She runs swiftly up and down the stems and over the leaves, both the upper and the under sides, often darting like a flash to another branch or to another plant.

The species must be rather common in the woods, for I have often seen her on the hunt and have several times seen her at work on her nest. She always selects the sloping sides of a pit as a location for her nest, at least I have never seen it at any other place. Fig. 24 is a photograph of the side of a pit perforated by holes dug by a number of species of *Oxybelus*, *Alyson*, *Bembex*, and others. There is an evident advantage to such a location over the usual position of a *Bembex* nest, which runs down from a level surface, for Mutillids of various sizes, running around in great numbers, never climb up a sloping surface to find the nests of digger-wasps.

The nest of *melleus* is always left open, day and night, which might give inquilines and parasitic flies a chance to get in. But the narrowness of the nest (two or three mm. in diameter) would keep out large flies and the great depth (12 inches) would tend to prevent smaller flies from finding the store of food.

The excavation is carried out after the usual manner of wasps, the sand being loosened with the mandibles, scratched back with the forefeet and kicked out with the hind pair. The work of digging the nest is all done at once, though some dirt is brought up from time to time after the provisioning has been begun.

My first specimen, No. 15, alighted in the bottom of the pit shown in Fig. 24 and walked over to her nest. It is the habit of the species to alight from three inches to a foot from the nest and then run over to it. No. 15 carried in her mandibles a small green leaf-hopper (*Tettigonia bifida*, Say). She entered the nest, remained inside a few seconds and was off again. She returned in three minutes with another leaf-hopper and made two more trips in seven minutes each by 5:19 p. m., when I left her. On my arrival at 10:00 the next morning she had been doing a little digging. At 10:30 she came up to the entrance waving her long antennae at me and looked out. She then protruded her whole head, examined the weather and slowly crawled forth. Soon another individual was running around, evidently getting ready for the day's hunt. This one was, however, destined to be shortlived, for she ventured too near a spider's nest, whose owner, a perfect mimic of the sand, was lying in ambush. Quick as a flash the spider was upon the wasp, gave it a bite and as quickly returned to its lair. The wasp collapsed in the same instant.

At 11:15 the first individual which I had been watching and which had returned into the nest, now came forth and, after making a locality study, was off.

As a storm was approaching, I captured the wasp on her next return, eighteen minutes later and dug up the nest. I found it to extend downward in a gentle slope for a distance of twelve inches to a chamber of one-half inch in diameter. The chamber contained seven leaf-hoppers but no egg.

Alyson oppositus is also common. It is somewhat smaller than *A. melleus* and shows its consanguinity to this species by the small round dot on each side of its abdomen as well as by its actions while on the hunt.

(e) RHOPOLUM (CRABRO) ABDOMINALE (FOX).

This wasp is rather abundant in August and September. The sexes can be readily distinguished as they fly around the low vegetation of the woods. The males have but one color, being wholly black, while the abdomen of the females is bright red in color. The thorax is very broad, which makes the abdomen, tapering gradually toward the pedicle as in the case of *Trypoxylon*, look very narrow. *R. abdominale* reminds me of *Trypoxylon* more than any other wasp in the manner of its flight, for both, while out hunting, are almost constantly on the wing and have a way of displaying their curiosity by touching with their antennæ every leaf or stick or blade of grass in their path.

Like *Diodontus americanus*, so well described by the Peckhams, *abdominale* has the habit of flying into her open door-way. It was this which first called my attention to her on September 14. The entrance to the wasp's nest was a tiny hole in the middle of a small flat elevation in the sand. The wasp approached the nest from various sides, but whatever direction she came from, she first took up a position directly opposite the entrance to her nest, where she hovered for the twinkling of an eye,—just long enough to give me a glimpse of the green leaf-hopper, which protruded a little beyond her red abdomen. After this momentary quiver in front of the nest, *abdominale* takes a beautiful bee-line right into her open portal. It is a pretty sight to see this dive into the nest; it seems to indicate a wonderfully keen sight for an insect thus to see the tiny hole from the height of four or five inches and to judge her flight so truly.

R. abdominale captures the same prey as *Alyson melleus*, leaf-hoppers of the species *Tettigonia bifida*, Say. She is a wasp of half the length of her competitor, but it takes her less time to catch her prey. On September 14th, she brought home seventeen to twenty leaf-hoppers, thirteen of which I saw carried in. The times at which this was done are as follows: 10:40, 10:55, 11:05, 11:20, 11:37, 11:35, 11:53, 11:57, 1:50, 1:57, 2:05, 2:09, 2:27. On each trip she remained inside but a few seconds. Her white silvery face was the first to appear at the entrance. Here she waited but an instant before she was off like a flash, often so quickly that I did not notice the direction of her flight.

Thyreopus (Crabro) argus shows the same haste in getting away from her nest and displays great acrobatic powers in the grace with

which she slips into it on her return. Only once did *abdominale* hesitate a little, flying around the nest in a zig-zag manner, before leaving. The work on the nest was continued for at least three days, since two days were spent in storing alone. I failed to trace this nest, belonging to No. 67, but succeeded in tracing that of No. 70. This went in nearly horizontally for two and a half inches and then down nearly vertically for four inches with a uniform diameter of two mm. The tunnel had a small pocket at the bottom containing a number of leaf-hoppers, but no eggs.

VI. AGENIA, THE AMPUTATOR OF SPIDERS' LEGS.

(a) AGENIA, SP. NOV. AND AGENIA ACCEPTA, CRESS., TWO DIGGERS.

The species of *Agenia* are the most agile of all wasps not even excepting those of *Pompilus* and *Aporus*. The genus is unique in that its members, I believe without exception, have the habit of cutting off their victim's legs. I have gotten glimpses of the doings of four species of *Agenia*; the two species first considered dig holes in the ground for their nests; the other species, which are considered separately below, build elliptical cells of mud in which to rear their young. Yet, though their nest-building habits differ so widely, their general appearance and their behavior when abroad in daylight make the genus easy of recognition.

Agenia (sp. nov.) and *Agenia accepta* are very closely related both as to habits and structural characters. The latter is half again as large as the former, is darker in color and has clouded wings. Both species have made a strong impression on my mind because of their striking resemblance to the Texas red ant, *Pogonomyrmex*. The new and undescribed species I have seen only in the sandy woods on the river bank below Austin; *A. accepta* only on the limestone hills in and about the city. The same fact of distribution obtains for the common species of *Pogonomyrmex*; *P. barbatus*, so common everywhere else in the surrounding country, does not occur in the sand land where *Poccidentalis*, var. *Comanche*, with its disc-shaped mounds, is very common. These two species of ants differ markedly in color and somewhat in size, *Comanche* being the smaller and of a lighter hue. The same differences exactly exist between *Agenia* sp. nov. and *accepta*, the former, the smaller and lighter species, occurring only in the sandy tract above mentioned. While this may be a mere coincidence it is worth stating that most of the individuals which I have observed, were either near or in the midst of a lot of red ants, which they resemble respectively in size and color. Whether this be a real case of mimicry or not, I would not say. But there is no doubt that the protection afforded is considerable as the sting of the red ants is very formidable and a thing to be dreaded, while that of *Agenia* is weak

and can scarcely pierce one's skin. The resemblance to the ant is moreover very much heightened by the transparency of the wings, by which these are rendered almost invisible. In fact, the first specimen I saw I at first did not distinguish from the dozens of ants in whose company it was running over the ground. My eye was attracted by a peculiar object lying on the ground, which proved to be a legless spider, and with so many ants running around, I knew that the spider could not have been lying there very long. Presently indeed, the wasp disclosed her identity by making several of her characteristic leaps of a foot or more from side to side, as she approached the spider. She grasped it by an anterior coxa and was about to make off with it, when, for lack of time to follow I captured her. The spider not only had all of the legs removed, but one of the palps as well. It was a large Epeirid, an immense load for the little wasp.

The second specimen of this *Agenia* which came my way was the most skilful acrobatic performer I ever saw. She was carrying an Attid as long and much heavier than herself; but the load seemed a feather's weight, for she carried it along so swiftly, so gracefully and with so little apparent exertion. She was carrying this spider in her mandibles and using her legs entirely for running up stems and over leaves. It was her method of progressing to climb the branches of weeds and bushes to their very tips, and then fly either across to another branch or onto the ground as far as she could. In this she resembled certain species of *Pompilus*, which, however, differ in climbing up stems and running on the ground backwards instead of forward. Every movement of *Agenia* was as certain as it was swift, for she never missed her aim in flying from branch to branch. Her descent even was easy and graceful and she came to the ground as lightly as a feather. Thus for a time she chased on from bush to bush, climbing up the stems and descending to the other side. Suddenly our pleasure came to naught by the interposition of the suspending thread of an *Agelina* web. In these the two were caught, the Attid sticking fast and the wasp escaping. Nor did the wasp ever return, for I left the spider over night and during the next morning finding it still on the same spot the following noon. The spider had all the legs cut off except the anterior right; the palpi were present.

I have seen this species out hunting on several occasions and have found her to be a most thorough hunter. All her motions

betokened the greatest excitement. In her quick flight from place to place, she strikingly reminds one of *Agenia accepta*, the second species, which darts around like her lighter cousin of the post-oak woods. I saw the first specimen on October 21st. Walking along the street, I chanced upon her as she dropped a large Attid among a stream of ants passing back and forth. She flew up as I drew near and I used the interval of her absence to examine the spider, which had all the legs amputated, though it was allowed to retain its palps.

Soon the wasp returned, grasped the spider by a coxal joint and carried it several feet further to the edge of a crevice in the ground. She then backed in, took hold of the spider and drew it down after her. Now came a test of patience which I failed to stand. After waiting three and three-fourths hours, I concluded that the wasp had escaped me, for I was used to quicker work of digging and storing a nest in sandy soil. I therefore dug down and found the crevice two inches deep, from the bottom of which the wasp had dug, almost vertically down, a nest one-fourth inch in diameter and three inches deep. Here I caught her, but failed to find the spider, which had possibly been left somewhere in the crevice.

The other specimen I saw was again advancing with its spider where foraging ants were numerous. In fact, as I followed her, she suddenly disappeared with her victim in a deserted entrance to the ant-nest. In this case the spider, as far as I could make out, had lost but one of its appendages.

It has not been my own good fortune to witness the amputation of a spider's legs by an *Agenia* but I here report the observation of my friends Messrs. Julius Egging and E. Jaeger on this operation as it was related to me. *A. accepta* and her spider were the centre of the quarter hour's excitement. The spider, a large gray Attid, was resting on a fence post when the wasp flew at it and administered the sting. To tell just how this was done was asking the observers too much. In an instant the victim was limp and helpless and the wasp immediately cut off one of the spider's legs, the shreddy bark of the cedar post affording the wasp a pretty firm foothold. The spider thereupon fell to the ground but the wasp soon found it again and proceeded to carry it off. The spider's legs, however, interfered with her walking, for, as I have observed above, *Agenia* straddles her victim and advances forwards. The wasp dropped her burden and set to work to cut off with her man-

dibles two more of the spider's legs. This was done very quickly; after one, two or three trials the leg snapped off like the end of a wire snaps off when a pair of nippers is applied. The spider was then taken up a second time but again set down owing to the interference of the remaining legs. A few more legs were again nipped off and this process repeated a number of times until the legs were finally cut off all around, only the palpi of all the appendages being left.

(b) *AGENIA SUBCORTICALIS* (WALSH), AND *AGENIA MELLIPES* (SAY).

In contrast to *A. accepta* and her ally just considered, *A. mellipes* and *subcorticalis* have a sombre hue in perfect accord with the dark recesses where they build their adobe cells in secret. *Mellipes* is metallic blue, almost black in color and measures about three-eighths of an inch in length; *subcorticalis* is somewhat larger and is distinguished by her red hind femora.

My only acquaintance among the members of the species *mellipes* betrayed the location of her home by the directness of her advance toward it. Under a leaf on the ground in the angle formed by two roots of a large elm tree was the wasp's nesting place and thither she was making trip after trip carrying pellets of mud for the construction of her nest. Like *Alyson melleus*, *mellipes* has the habit of alighting on the ground a little distance from the nest and covering this latter part of her journey on foot. She enters the archway that conceals her nest without hesitation but is more cautious on departure, looking out on the world and waving her long antennæ before darting away on her errand. The wasp paid no attention to me; I was nothing to her, nor were, apparently, any of the other objects of her environment. For I took away some stems of poison ivy that obstructed my view and endangered my health; I even pushed back the leaf that covered the nest in order to observe her work—all this, without affecting her comings and goings in the least. *Agenia* was building her third cell; and since thirty to forty more trips are needed to complete each one, her familiarity with the surroundings finds an easy explanation. From 4:30 to 5:15, July 31, *mellipes* made fifteen trips requiring from one to five minutes each. The little round pellets of mud which she carried home in her mandibles were added to the cylindrical wall until it had been built out to about

the length of the wasp's body. Fifteen to twenty seconds was sufficient time for the wasp to apply each load of mortar carried home. After the required length of the cell, which now looked a good deal like a barrel lying on its side, had been reached, the inside was carefully plastered and calcimined with a number of pellets of mud, the wasp reaching in for her whole length and at times working upside down. Possibly the wasp was adding an extra amount of saliva to this last work thereby manufacturing a kind of varnish with which to increase the durability of the structure. At any rate the interior presents a smooth surface while the exterior is very rough, each elevation representing the amount of mud brought in by a single load.

At 5:15 the cell was ready to receive the spider with which it was to be stored. *Mellipes*, however, does not have good luck in finding the spiders she wants. On this occasion it took her twenty-four hours to store the cell, on another forty-six hours elapsed between the completion and the storing. At 6:30 p. m., August 1, the wasp was just putting the finishing touches on the disc-shaped lid with which she closed the cell. I failed to catch the wasp at this time though I succeeded ten days later while she was at work under another leaf in the same angle of the elm tree roots.

The wasp had built three barrel-shaped cells tapering slightly at both ends, each cell about eight mm. long and four in greatest diameter. One cell was independent of the other two which were built together at an angle of about 120 degrees. The angle seems to depend on the conditions under which the cells are built, for I once found in a narrow crease of a wagon cloth five cells of *mellipes* attached one to the other in a straight line. Having reached home with my trophy I could not resist opening at least the cell last made to ascertain the condition of the spider and the position of the egg. Both are well shown in Fig. 20. The spider, it will be seen, had lost all its legs but the front pair and the egg was placed across the ventral surface of its abdomen. The spider was stuffed into the cell head first.

But egg and spider were not the only occupants of the cell. To my great astonishment I became aware of a tiny parasitic wasp, no larger than *Agenia's* egg itself, resting on the egg. The parasite (*Ophelinus florifrons*, Ashm.) had been imprisoned and when I found it, was evidently about to infect the egg of its host. It had not yet laid its own eggs into that of *melipes*, however, for the

latter developed normally. It hatched and the larva in due time devoured every trace of the spider. August 8 it spun a fine white cocoon, which, it might be added, never changed its color. This is also true of the cocoons of *A. subcorticalis*. The larva succeeded in spinning its cocoon with support only from the low sides of the broken cell. It is also significant that the larva and pupa both developed quite as well in the light and without the protection of the mud cell, also in the dry atmosphere of the laboratory, as they would have done in their natural haunt on the banks of Waller Creek. The adult, a female, emerged August 23, just twenty-two days less three hours after the egg was laid. The adult from cell No. 2, also a female, emerged by a small round hole in the side of the cell on August 22 and the total length of its development was twenty-three days. On August 16, nineteen and one-half days after it was stored and closed, the oldest cell brought forth thirty to thirty-five parasitic wasps of the species mentioned above. *Agencia's* cocoon was present but its contents had been devoured by the larvae of the nefarious swarm which darted around on the inside of my collecting bottle clamoring for exit.

My first acquaintance of the species *A. subcorticalis* was running along in a hop-step-and-jump fashion carrying in her mandibles a large legless Attid. She ran up a tree for a foot and dropped her burden to the ground. Before she could recover it another *subcorticalis* was on the scene and a struggle for the spider ensued. The intruder caught it up and ran with it into a crevice in a tree as if to hide there. But the rightful owner recovered her quarry and made away with it in all haste, mounting a slender sapling to the height of twenty feet, and was lost to view. The other wasp continued her search for a while but she too soon disappeared.

Spiders are not the only creatures that will occupy the abandoned cells of an old mud-dauber's nest. *Trypoxylon* finds them a very convenient abode (Fig. 23) and even the graceful and handsome *Agencia subcorticalis* will not disdain to build her little cells and rear her young where an inferior *Pelopoeus* has been born. *Trypoxylon* uses the whole lumen of the empty cell as it is, merely closing the opening after the cell is stored. But *Agencia* uses the cells merely as cavities in which to build her own small cells of the ancestral type. Thus she may have as many as five of her own mud cells inside a single chamber of the big mud-dauber's nest. Indeed *subcorticalis* goes a step farther and not only closes each one

of her own individual cells but builds a plug over the opening to the large chamber just as the original proprietor would have done, thus offering an additional rampart to her enemies.

The dirt which *Agenia* uses is taken from the very nest in which she is building her own. This makes it very convenient for her, of course. She gnaws off her pellets, moistening the dirt as she works. As I have observed in the case of *Trypoxylon* the supply of water necessary for moistening so large an amount of dry dirt must soon give out. So after a number of trips *Agenia*, like *Trypoxylon*, flies away to get a drink of water and then returns to resume her work. She wisely economizes in her use of water by returning each time to the same spot, moistened by the previous visit, for each successive load.

A considerable number of dirt-dauber's nests were thus occupied by the new tenants. Owing to the lateness of the season many contained pupæ waiting in their clean white cocoons for the advent of spring. Of the five spiders examined one remained in possession of all its appendages, one had the left hind one cut off, another had missing three hind legs on the right side, a fourth had only its front pair left and a fifth had lost all its legs. All the spiders were Attids of the same species.

In each of the above cases of spiders deprived of legs, death had ensued even before the storing of the victim. I have, however, found mud cells containing mutilated spiders that were very much alive when found. In the spring of 1903, I found under the bark of an elm, a single cylindrical mud cell containing a young legless Attid that snugly filled the cell. This spider was alive and remained alive for at least a week. On October 21st, I found two cells under a stone, one of which contained a Clubionid, that lacked the hind pair of legs and the two anterior ones on the right side. It was not only alive, but would cling to a pencil held close to it and would bite at it. The spider remained alive until the larva began feeding. The egg was attached to the right side of the abdomen near the pedicel and there the larva on hatching attached itself and began eating. The pupa was spun November 5th.

The amputation habits of *Agenia* are interesting not only because of the rareness of the habit among wasps, but because it seemed to have developed in this genus as the regular method of procedure.

VII. SOME OTHER SPIDER RAVISHERS.

(a) *POMPILUS MARGINATUS*, SAY.

This species of *Pompilus* has had its story well told by previous admirers. The single specimen, whose ways are here described, while agreeing in mental traits with her northern sisters, still, in my opinion, deserves a mention among her southern relatives to which these pages are devoted.

August 2d was a fine, hot day and my early expectations of some interesting performances by my insect entertainers were fully realized during the day. At 9:45, I came across a small *Pompilus marginatus*. The sprightly little spider ravisher alighted on the ground and hopped about in great agitation. I had often seen the species on the hunt and was anxious to see one in a duel with the eight-legged enemy of her race, or at work digging and storing the nest. She was at this time much more excited than when on the hunt; and she soon began to dig at a number of places only a few inches apart, showing that she was looking for a suitable place to dig her nest. After eight minutes of trial, she finally settled upon a place that seemed to suit her, little realizing, however, that she had chosen for the home of her offspring, the middle of a much used path through the sandy woods. Here she began to dig with vim and in a few minutes had dug a hole an inch or more in depth and was bringing out the sand at regular intervals, which increased in length with the increase in depth of the nest. The sand was pushed up in loads with the hind legs and the end of the abdomen. The wasp did not appear with a load each time, but often five or six loads would be allowed to accumulate at the entrance, when the whole pile would be pushed out and scattered away from the entrance more or less carefully. All the work was done in feverish haste. While busy on the surface, the furious little worker held her wings straight up in the air, at times vibrating them and making them flash in the sunlight.

Marginatus is a species that catches her prey before digging her nest and she did not delay long to make known where the spider was located. At 9:56, i. e., after the wasp had been digging but a minute, she left her nest and ran off among the grass and weeds

growing sparsely along the path. While running, the tiny worker betokened even more feverish excitement than when digging, for she ran swiftly with her wings standing out obliquely and in continuous vibration, giving her a most comical appearance. Three feet from the nest the spider lay on top of a pinnatifid leaf of *Achillia*, excellently adapted to hold the spider and keep it out of reach of the many ants everywhere running around in great numbers. (Fig. 5.) During the hour and eight minutes that it took to dig the nest (from 9:56 to 11:04), the wasp made six visits to the spider after intervals of one, five, nine, thirteen, thirteen, and thirteen minutes, each time returning to the nest in the same excited manner. The visit was sometimes made partly on the wing, the wasp flying from one of the intervening plants to another. Her sense of direction was, however, not absolutely true, for only once did I see her go straight to the spider. Usually she passed it several times before coming upon it. On the way back, the nest was found without much difficulty.

At 11:04 the nest was apparently finished, for at this time the wasp ran over to the spider again, grasped it by one of the coxae and advanced with it to within fifteen inches of the nest, where she dropped it to reconnoitre the ground and re-examine the nest. The next advance was to within one and one-half inches of the entrance, when another survey had to be undertaken. The next spot was within an inch of the nest which was again examined. Assured that all was right, the spider was once more picked up, and this time taken in. In being taken in, the spider first took a position with its long axis across the entrance; but the wasp, which had backed in, got hold of the posterior end of the spider and pulled it inside. It seemed to go in smoothly, though two of the legs were directed backwards. The wasp remained inside for fifteen minutes and finally appeared scratching in sand and stepping it down into the nest. When this was nearly full, she pulled down the dry sand from above the entrance, biting it loose with her mandibles. After a few minutes rest in the shady corner of a human foot-print, she returned, smoothed over the entrance for a moment or two in a wider circle than before and flew away.

I immediately dug for the spider that had been just entombed and came across it four inches from the opening of the nest and three inches below the surface. It was lying in a chamber large enough to hold it with outstretched legs.

The egg, one mm. in length, was placed on the dorsolateral side of the abdomen near the pedicel, as shown in figure 12, which is natural size. The spider had been stung to death since it never responded to stimulation and was soon overtaken by mould. The egg never hatched.

(b) *POMPILOGASTER FUSCIPENNIS* (LEPEL).

This wasp with black legs and thorax and bright red abdomen is a furious hunter, flying from plant to plant in a whirlwind. No wonder therefore that I lost sight of a specimen so suddenly one afternoon as she was carrying off her prey. A flash of red and green is all I saw as wasp and spider tumbled down a hole in the sand and disappeared. The hole lead into a burrow that had been dug by some rodent and extended for many feet just beneath the surface of the sand. I have noticed other spider ravishers choose such a place to hide their spider and to dig their nest. Solid black soil, which cracks in dry weather, offers more opportunities in this way than does the sandy land where most of my observations were made.

The wasp remained inside the burrow one hour and twenty minutes. Thinking that the wasp had by that time escaped at another point along the burrow, I dug this up and came upon the wasp, that had buried the spider in a shallow hole which it had dug in the side of the burrow. The spider, which was dead, was a large green "cotton spider" belonging to the genus *Dolomedes*. The wasp remained in the vicinity for half an hour, when I caught her.

(c) *POMPILID THAT DOES NOT BURY ITS PREY.*

In the Cambridge Natural History, vol. VI, p. 106, Sharp makes mention of Emery's account of "some Pompilids that do not bury their prey but, after stinging it and depositing an egg, simply leave the spider on the spot." Such an one came flying about our veranda with businesslike airs one fine July day. She was of a brilliant metallic blue, somewhat lighter than *Pelopaeus coeruleus*. She looked into every nook and cranny of the walls that struck her fancy. Finally she remained some little time behind a detached piece of wallpaper from which the edge of a spider's web protruded. Looking down I saw the wasp tugging away at a spider; but this

had its claws so thoroughly entangled in its web that the wasp was forced to desist.

After stinging this spider the wasp spent five or six minutes flying about, resting on the rafters or running up and down the walls. At the end of this time she disappeared behind the head-casing of a door where another spider had spread its web. Presently the wasp came forth dragging the spider backwards over its own web with her mandibles fastened to one of its front coxae. The spider was deposited a few inches below the edge of the casing on the margin of its own web and the egg laid upon it. At 3:07 the wasp was out and flew airily about and in a minute was off and away. At 3:20 she returned to the first spider on which, after removing it, I found an egg. I can not say whether she laid the egg at the first or at the second visit. In either case it is certain that two eggs were laid in less than fifteen minutes.

The first spider never showed any signs of life but soon withered. The egg died from an injury received in the handling. The second spider lived till half consumed by the larva. This spun its light cream-colored cocoon (which turned yellow in a few weeks) ten days after the egg was laid. Late in August the adult emerged by cutting and lifting a circular cap from one end of the cocoon after the manner of *Ichneumon* flies. This specimen was a male and it was therefore impossible to identify the species.

(d) *MISCOPHUS* SP?

Nearly all kinds and sizes of spiders have their wasp enemies, from the giant tarantula, which is hunted by the powerful *Pepsis*, down to the young spiderlings captured by *Miscophus*. This species is a tiny black wasp hardly four mm. in length but very active for her size and just as "bright" as any of her big sisters.

She digs her nest with mandibles and forefeet like most digger-wasps. She is not particular about cleaning away the sand from in front of her nest for any great distance while she is busy digging it, with the result that the sand kicked out collects in a semi-circle in front of the nest. When the nest is completed and ready for occupancy and, indeed, when it is left temporarily, it is usually carefully closed with sand and the surface in a radius of several inches is often smoothed over in a neat and tidy manner. She is extremely sensitive to one's presence. When she is carrying a

spider, a slight motion on my part will make her drop her burden and fly away for a minute or two.

Miscophus catches for her prey young Epeirids of convenient size. These are carried home on the wing if very minute; medium-sized ones are carried in small jumps like the crickets of *Larra*, the length of the jump depending on the weight of the burden; larger spiders are carried on foot. I have seen no Pompilid carry her spider quite like *Miscophus*. This wasp grasps the paralyzed spider with her mandibles by two or more of its legs, "slings it on her back" and marches off with it, walking forward, the spider hanging rather to one side in an uncomfortable and awkward looking manner. Arrived at the nest, the wasp opens it, enters and drags her prey after her. After the nest has been stored and the egg laid, the tunnel is closed with sand and the surface smoothed over with fastidious care.

I opened two nests each of which contained six spiderlings, the largest in each nest having attached to its abdomen near the pedicle a minute egg. I did not succeed in rearing any adults for each of the two larvae died after having lived a larval life of five days and spun an incomplete cocoon.

The nests were astonishingly small. The first had a tube two mm. in diameter leading slantingly downwards for a distance of three centimeters to a pocket measuring five mm. across. The other nest was dug in a small clump of dirt which was itself hardly three centimeters in greatest length. The nest measured but fifteen mm. ($\frac{5}{8}$ inch) in length *including* the round pocket, five mm. in diameter, which harbored the spiders.

Miscophus, though the smallest in size among the spider hunters, is not least in interest nor does she hold a place in my esteem proportionate to her size.

VIII. TRYPOXYLON TEXENSE (SOUSS), A PET OF THE HOUSEHOLD.

Several species of *Trypoxylon* have been admirably described by Mr. and Mrs. Peckham in their delightful book already frequently referred to. I would not presume to attempt to improve in any way on their account of this so well "domesticated" genus; yet I hope that the few new observations here presented on the Texas species may be of interest to the reader.

The many scattered notes I have made on the doings of *T. texense* agree in essentials with the observations set forth in the work just cited. In disposition the southern species is also amiable and good tempered and is most tolerant of the actions which curiosity prompts the observer to take, up to the point of destroying the nest itself. The male of *texense*, when present, remains faithfully on guard in the nest during the absence of the female. I have found a large proportion of the nests without males; in such cases the female went on with her household duties as well as when joined by her vespine consort. In one case a male remained alternately on guard in two contiguous nests; when both females returned at once the male exhibited more than the usual amount of excitement in spite of the fact that neither female paid any attention to him. On the presence of the male in the nest of these wasps I shall perhaps in a later paper have more to say, for I believe the subject worthy of further investigation.

In the selection of a nidus *texense* exhibits the same habits as *rubrocinctum*, occupying almost any small crevices in wooden or stone walls. Beetle burrows in the cedar posts of log cabins along the Colorado River are nearly all occupied by *T. texense*. Fig. 23 represents a pair of these wasps occupying a cell of an old mud-dauber's nest. I have found it very convenient to attract the wasps by setting out for them blocks of wood with holes bored in them. The wasps will make use of borings one-half inch in diameter but prefer tubes of smaller calibre. It does not seem to make much difference whether the tube is horizontal or vertical, both conditions being acceptable. I have found several two-story nests in

empty shot-gun shells standing upright. In these the partition and the plug were each in two layers, an inner of white and an outer of yellow clay, each layer being a millimeter in thickness. In getting the nest ready the only thing I have seen *texense* do is to plaster a few pellets of mud against the bottom of the tube. Thus the cap hole of the shot-gun shell was tightly closed with it. The length of the chambers depends on their calibre and varies from three-fourth inch to one and one-half inches. When a nest is composed of several cells in horizontal series, the partition is built from the bottom up and is therefore thickest at the bottom. In closing the last chamber an extra amount of mud is plastered on and the plug is brought flush with the surface. In about half the cases the final closure was made with two plugs from one-fourth to one-half inch apart leaving an empty space or false chamber between them. This must certainly be an effective means of deceiving such parasitic enemies (should they have any) as lay their eggs by means of boring ovipositors into the nests of their aculeate hosts.

T. texense has a way, as I have already pointed out above, in connection with *Agencia subcorticalis*, of economizing time in the matter of getting mortar for the nest. I had always thought that this was gotten from the moist banks of the creek or river, whither *Pelopaeus* pilgrimizes for her building material. But it is certain that many do not get mud from that source but instead take it from the nearest place obtainable, namely those great pyramids of the world of wasps, the abandoned mud-dauber's nests just at hand. Soon after I had begun inducing *texense* to make her home with us and build her nests on the gallery of the Lucksinger country home, the old mud-dauber nests began to decrease perceptibly in size, their material being used again in similar architectural enterprises. *Trypoxylon* flies from her nest to a suitable place on a mud-dauber's nests and begins to gnaw off a piece of the dirt with her mandibles moistening it with saliva as she works. *Pelopaeus'* old house is hard and one can hear the grating and clicking of *Trypoxylon's* mandibles upon it as well as the hum of her wings under the strain of her work. Finally a pellet as large as her head is loosened and the wasp, just as the pellet is ready to drop, catches it "under her chin," as it were, and takes it to her nest. The dirt is moist when plastered on and one can see the moist spot from

which a wad of it has just been taken. To this same spot the wasp returns for successive loads, thus economizing in the expenditure of saliva necessary to wet the dirt. This requires, of course, more moisture, even for a single partition, than the wasp's body can well hold and it becomes necessary to replenish the stock at intervals. So I have noticed that after every four or five loads the wasp flies away in the direction of the creek, seventy-five yards distant, presumably for a drink, and returns to continue her work where she left off.

Like *T. rubrocinctum* a day's work with *texense* consists of at least storing and closing one cell, though two cells a day is not unusual for her. Of those individuals on which I have detailed notes one stored two cells in one day and one cell the next forenoon, two others each two cells in one day, one stored nine Attids, one Thomisid and three Epeireds and closed the nest all in three and one-half hours; another stored and partitioned off one cell in eight hours and stored and plugged up the second cell in ten hours. Thus *texense* is more industrious than *rubrocinctum*, which shows that a semi-tropical climate is not enervating to the wasp race at least.

The development of the young wasp is more rapid in the Texas species than in the northern. The period required for the egg and larval stages of *texense* together varies from six and one-fourth to seven days and averages nearly seven days. One larva spun its cocoon in five and one-half days but never reached the imago stage. The length of the pupal period is a little more or less than thirty days.

T. texense captures eight to twenty-five spiders for a single cell, the average being about fifteen. When a nest is composed of two superposed or adjoining cells the deeper one or the one first stored has invariably the greater number of spiders; the difference is specially noticeable when both cells have been stored the same day. The wasps seem to have a decided sense of fatigue, which is quite natural. The great majority of the spiders are alive when brought in; the majority of these live to about the third day. This accords with the findings of the Milwaukee students in the case of *T. rubrocinctum*.

T. texense begins work early in the year and is on the crest of her prosperity at the time *rubrocinctum*, her northern cousin, is

"losing interest in the family affairs and taking a well-earned holiday on the blossoms of the aster and the goldenrod." *Texense* is our most common solitary wasp next to the red *Pelopaeus*, among which she may be seen at work, the former decorating(?) the wall with her edifices, the latter modestly occupying the out-of-the-way crannies and crevices that might otherwise be used by spiders as their retreats.

IX. SOME ENEMIES OF THE ORTHOPTERA.

(a) LARRA AMERICANA (FOX), AND HER CRICKETS.

The first specimen of this species which I chanced upon was digging her nest on the edge of a small precipice at the bottom of which lay three crickets, all kicking violently, one even almost able to crawl away. Her manner of digging was peculiar among the solitary wasps I have seen. While she proceeded in part by scratching the dirt back under her much like *Pompilus* and with equal vigor and nervousness, she pushed out the loads she accumulated in a different manner. Other wasps use chiefly their hind legs and abdomen; but this specimen used her head and front legs, improvising of these a kind of scraper. To take on a load of sand the wasp stretched out her legs, lay down flat and pushed her head in the sand and backed out. On account of this method of digging, the burrow resulting was wide and low, so as to make room for the outstretched legs.

There was something wrong with this individual of *L. Americana*. She soon lost interest in her work, ran around looking into other nests and other holes in the ground. She acted in a most demented manner. Her visits to her old nests and to her crickets became fewer and fewer and she finally remained away altogether.

My second specimen I followed to her nest on the nearly vertical bank of a creek near Austin. She was carrying a large cricket in her mandibles and was moving along in jumps of a yard or more. She alighted at the bottom of the embankment and walked up its steep side entering a large hole, from the further end of which she had dug her nest. In this way I saw her carry in four crickets of various sizes. Two days later I found the nest closed with earth, though not quite to its mouth. I dug up this nest as well as another close by and found both to have been of about the same shape and dimensions. A tunnel five-sixteenths inch in diameter ran into the embankment at a slight inclination downward for a distance of four inches. It ended in a dilatation, one of the pockets of the nest. Just in front of this the tunnel branched off for a slight distance and lead into another pocket which was the larger as well

as the one first made. In this six crickets had been stored, all of which but one (which was dead) were not only alive but positively lively. One, indeed, after I had dug out the nest, very nearly got away from me. The smaller pocket contained but one large and one small cricket, both very much alive. The larva in each case had attached itself to the prosternum of the most active cricket and curved around the body of its host, thus embracing it for better protection. Larval *americana* does not eat any of the hard parts of its viand, but reaches into the thorax, abdomen, head and legs to procure the meat and suck the juices. After five days the older larva (ca. six days old) had devoured its store of food while the other had eaten but one large cricket. Both spun an imperfect cocoon and soon died.

Tachytes abductus (Fox), var.? is a rather common Larrid in this locality. The wasp is black and in the sunlight there is a shimmer of bronze between the segments of the abdomen. The species catches nymphal short horned grasshoppers, carrying them closely pressed to her venter with her legs. She is to be admired for the reluctance with which she betrays the whereabouts of her nest.

(b) PRIONONYX THOMAE (FABRE), THE LOCUST KILLER.

As late as October 9th, after her northern cousins had begun to lose interest in the affairs of life, *Priononyx Thomae* was as busy as ever. My only specimen of this interesting wasp flew up from her nest as I came down the well-worn path where she was at work. A flash of red was all I saw at first; from this and from the shape of the nest on which she was engaged, being a round hole leading straight down, I was led to believe that the creature I had disturbed was none other than *Ammophila*. *Priononyx* soon returned, however, and proved that she was an entirely new acquaintance, though her subsequent actions clearly showed that both she and *Ammophila* had inherited mental traits from the same not very distant ancestors. She is more stoutly built than *A. procera*, is smaller and is black with the exception of her abdomen which is bright red in color.

A faster worker never lived than *P. Thomae*. But her speed is due to a deliberate haste and not to the insane, wasteful hurry that seems to characterize the actions of many species of *Pompilus*. At 1:30 she returned to her burrow which she had dug down to the

length of her body. After working at it for a minute she abandoned the nest for some reason, filled it with sand to the top and started a new one near by. Although digging in a well-worn gravelly pathway she made astonishing progress. Biting the pebbles and smaller sand grains loose with her powerful jaws she scratched the loose material out with her fore-feet or carried the larger pieces out with her mandibles. Her movements had almost machine-like regularity, entering the nest forwards and invariably backing out. Back and forth she went, darting in and out so quickly and smoothly that I can best compare her movements to those of a rubber ball attached to the end of an elastic band. After thus working for nineteen minutes, *Priononyx* flew away to a distance of twenty feet where she pulled forth a large green locust. Straddling her prey like *Ammophila* and grasping one of the short antennae she ran swiftly down the path. Within two feet of her nest she carried the grasshopper into a tuft of grass, which she easily mounted with her burden thanks to the length and the strength of her legs. After then digging at her nest for five minutes more she took up her victim as before and carried it over to her nest, laying it down with its head near the entrance. She then, like *Ammophila* again, backed down the tunnel and pulled the locust after her. In a minute she reappeared and immediately began to close the tunnel. Scratching in pebbles and dust, she tamped them down with her head. I now placed a net over her but she worked complacently on. I could see her every action through the thin net, for she worked but a foot below my eyes. After the net was full flush with the surface good sized pebbles were carried over it. Time and again these were tightly grasped in her mandibles and pressed down with might and main, the wasp standing the while straight on her head and almost turning a summersault while her busy buzz indicated the exertion which the operation demanded. Then she dug awhile in the abandoned hole she had previously filled in but soon quit digging and filled it in a second time. I slightly raised the net and *Priononyx* flew away.

An hour later she was again at work only a few inches from the scene of her previous operations, digging another nest. Three feet away I found another green locust under a clump of grass—another prey for another nest. Thus it seems certain that *Thomae* first catches her prey and then digs her nest. At this juncture I caught her.

The greatest surprise was, however, yet in store for me. With a pick axe I dug a hole about a foot deep at a safe distance from the nest and with a trowel worked away the hard earth carefully in the direction of the nest so as to lay it open and yet not injure the grasshopper or the egg upon it. To my surprise I came upon a nest sooner than I had expected; to my still greater surprise the grasshopper had not an egg but a good-sized larva upon it. A second nest was then revealed and a third and so on until eight had been opened and I had lying before me a collection of nine caterpillars, including the one not yet stored. All the nests were scattered over a space not larger than half of this page. The chamber was oblong (long axis horizontal), about two inches in length by $\frac{1}{2}$ to $\frac{7}{8}$ inch across and two inches below the surface. Some of the chambers were so close that they had but a $\frac{1}{4}$ inch wall between them. Just at what point the tunnel (which measured $\frac{3}{8}$ inch in diameter) entered the chamber, I could not exactly determine but think that it come off of one end, which would make the shape of *Thomae's* nest nearly like that of *Ammophila procera*. (Fig. 22.)

In each case the egg or larva had an exactly similar position on the locust. This was just above the coxa of the hind leg (which in one case was torn away) i. e., between the articulation of the coxa and the locust's "ear." The only variation in this regard was that in four cases the egg or larva was placed on the right and in four on the left side of the locust.

The egg of *P. Thomae* is slender and about 7 mm. in length. It arches from its point of attachment over the coxa of the hind leg, which, though the free end of the egg touches it, cannot easily injure it no matter how much the locust may be kicking. The egg is yellow with the exception of the two hyaline ends. Its anterior third is white and the extreme attached end is a watery hyaline disc. Like the egg of *Ammophila*, that of *Priononyx* does not seem to hatch. The first indication I perceived of larval life was the appearance of tracheal tubes down each side and later the sucking movements on the inside of the translucent larva.

Below I give the data on the condition of the nine locusts found Oct. 9th and the development of the larva:

No. 1.—Locust not yet stored. Dead when found.

No. 2.—Locust kicks violently without stimulation. On touching, it will jump two feet. Egg dead. Locust lived four days.

No. 3.—Locust twitched spontaneously from time to time as long

as Oct. 11; legs and mouth parts do not usually twitch simultaneously. Egg was the one most recently laid (Oct. 9). Larva spun cocoon in night of Oct 14-15. Length of larval life $5\frac{1}{2}$ days. Cocoon soon turned dark brown.

No. 4.—Locust a great kicker; jumped three feet with egg upon it; lived till Oct. 11, when wasp grub was nearly half grown. Very young larva showed tracheæ when found (Oct. 9); begun to spin cocoon at noon Oct. 14; cocoon light brown next morning.

No. 5.—Locust kicked violently when irritated as long as Oct. 10 though larva was 7 mm. long and half as thick. (The larva after a few days is shorter, though very much thicker, than the egg when laid). Larva spun cocoon a. m. Oct. 13.

No. 6.—Same as No. 5.

No. 7.—Very small locust was dead when found for larva was itself nearly as large as its victim; locust devoured Oct. 11; very small cocoon spun Oct. 12.

No. 8.—Large locust dead; large larva reaching into thorax. Cocoon spun a. m. Oct. 13.

No. 9.—Locust dead; devoured Oct. 11. Oct. 12 larva tried to spin cocoon but failed and died.

From these data it would seem that there were three sets of grasshoppers according to the age of the eggs or larvæ upon them. The facts go to show that the first three were captured Oct. 9. No. 4 might possibly also have been captured and stored early the same day, though more probably late the day before; Nos. 5 and 6 were certainly stored Oct. 8th. Nos. 7, 8 and 9 were stored Oct. 7. Thus this *P. Thomæ* accomplished the feat of digging in hard soil and provisioning three nests a day for three days in succession. It is also significant that all these nests were made in such close proximity. The locusts were all of the same species and were, in all cases but one, I have reason to believe, entombed alive and lived until killed by the wasp-larvæ themselves.

In many of her ways *Priononyx Thomæ* reminds one of *Ammodiplosis* in her general demeanor; in running in and out of her nest while engaged in its excavation; in the shape of her nest; in the manner of carrying her prey, in laying it down at the entrance and backing inside to pull it after her; in closing the nest and pressing pebbles down upon it as if to add some finishing touches intended to be ornamental as well as useful.

X. EXPERIMENT ON THE SENSE OF DIRECTION OF *CERCERIS FUMIPENNUS*.

The Sense of Direction of animals, particularly of Ants, Bees, and Wasps, is a subject which has engaged the attention of many naturalists. From my own observations on social and solitary wasps I incline to the opinion that these are guided mainly by sight in which familiar objects in the environment of their nests are important factors.

A rather decisive evidence of the important role played by trees, bushes and other objects in the orientation of insects is afforded by the actions of one of my friends, *Cerceris fumipennis*. On October 24th I discovered her bearing a weevil (*Chonotrachelus neocrataege*) into her nest, which was situated on the edge of a five-foot embankment just under a bush some two feet high. The next day I returned, cut the bush off at the roots and placed it three feet to the right. Soon *fumipennis*, too, returned and flew, not to her nest but to the bush which I had placed to one side. After discovering her mistake she flew away to get another start, came down again from between two trees and flew to the bush. Since she repeated this performance at least a dozen times without finding the nest, it is safe to conclude that it was the bush which directed her flight. Moreover, the wasp always flew down from the same direction, showing that earlier in her course she was directed by other objects, especially trees. This latter observation I have several times made on wasps whose nests I destroyed before the owners had completely stored them.

As a matter of fact, the power of finding their way is not so perfect as one might be led to suppose. Many spider-ravishers have great difficulty in finding the spiders which they hid or hung up while digging their nests. I have seen individuals of *Bembex texanus* and *Monedula carolina* so far lose track of their nests as to fail entirely to find them again.

In view of these and other facts I should agree with the Peckhams in the opinion that wasps have no additional sense, the sense of direction, in the common acception of the term, nor that they find their way by a process of dead reckoning as Darwin suggested, but that they find their way by a detailed familiarity with objects near the nest and by a general acquaintance with the locality in which they pass their lives.

SUMMARY AND CONCLUSIONS.

The present paper comprises more or less detailed observations on some 28 species of Texas Solitary Wasps. It was not written for the purpose of entering the discussion of mooted questions of instinct and intelligence, but rather of describing clearly and accurately the actions of some of these delightful little workers in their natural haunts.

My experiments on the mental faculties of wasps have been few and therefore of little value. The experiment recorded above on the sense of direction I have considered of sufficient value to be put down. It certainly has to commend it an absence of artificiality having been made by merely varying the natural conditions to which the wasp was already accustomed. In general my observations lead me to accord with the opinion held by the Peckhams and others that wasps are guided by sight in finding their way—by sight and the memory of familiar landmarks in the neighborhood.

Of the variability of instincts within a given species there can in my opinion be no doubt. The variability in mental traits and dispositions as reflected in the wasp's actions, seems moreover to be proportionate to the physical variability. At any rate, *Bembex bel-fraegi*, the species of *Bembidula* and *Microbembex monodonta* for example are all very variable species in size and coloration as well as in the demeanor of different individuals.

All the species of solitary wasps either dig holes in the ground for their nests or work with mud in their architectural pursuits. In the case of *Agénia* (Chap. VI) both kinds of nests are found in the same genus, some species digging typical nests in the ground while others build mud cells in protected places. This fact alone, it seems to me, would justify the setting-up of a distinct genus, *Pseudagénia*, as is done by some authorities. Among the wasps that dig their nests we may recognize two methods of excavation: in one the wasp utilizes the forelegs to scrape out the dirt loosened by the mandibles; in the other the wasp employs the mandibles both as pick and as shovel. *Ammophila* (Chap. II) and *Priononyx* (Chap. IX) represent the latter method and their nests are composed of a vertical tunnel leading straight down from the surface (Fig. 8) to a pocket whose long axis lies horizontal (Figs. 18 and 22.) The wasps work-

ing by the scratching method and employing their forefeet as rakes in excavation have simple nests consisting of a tube running obliquely down and ending in a dilation or pocket at the lower end of greater or lesser diameter (Figs. 19 and 21.) Among the mud-plastering wasps we may distinguish two methods of work again: Some species build the entire nest of mud, as for example *Agenia*, *Pelopaeus*, while others occupy convenient crevices, and use the mud-mortar merely to close the mouth of their ready made nests, as obtains in the case of *Trypoxylon*. The same genus may have species some of which practice the one, some the other method (*Odynerus*, Chap. I). And again the same species, as *Agenia subcorticalis* seems to do, may combine the two methods, for she builds complete cells of mud not in the open air like *Pelopatus* but hidden away in crevices.

Some wasps always carry their prey on the wing and on their return to the nest alight directly in or over its entrance. *Bembex*, *Monedula*, *Bembidula*, *Hoplisoides*, *Microbembex* carry their prey with their middle pair of legs and press it closely to their venter; *Rhopalum abdominale* and *Notoglossa* use their hind pair; *Odynerus*, *Trypoxylon* and *Cerceris* carry theirs with their mandibles as does also *Alyson*, which alights some distance from the west and completes her journey on foot. *Larra americana* and *Microbembex* prefer flying to walking; but when the weight is great the advance is in jumps or short flights, the distance of each advance being inversely proportionate to the weight of the burden.

Other wasps always drag the victim over the ground regardless of how light this may be and how absurd it may look (to us). *Amomphila*'s method, to which that of *Priononyx* corresponds, is shown in Fig. 16. Some spider catchers (*Miscophus*, *Agenia*) walk forward in dragging their prey; others (some species of *Pompilus* and *Pompilogaster*) always walk backward. *Agenia* and some others combine the flying and the walking means of progression. These drag their victims over the ground, climb up the stems of herbs and bushes in their path and fly off, parachute-fashion, from the highest point obtainable in the direction of their course. The species differ greatly, too, in the ease or reluctance with which they betray the locality of their nest, *Miscophus* and *Tachytes abductus* being, for example, experts in leading the observer astray.

By the way in which a wasp enters the nest the species may often be recognized. *Bembecids* as a rule, after having opened the nest

and on entering it, head foremost, deftly pass their prey back from the middle to the hind pair of legs. *Microbembex*, for example, never fails to do this regardless of the size, weight, or shape of the prey. *Ammophila*, like *Priononyx Thomae*, lays her victim down beside the entrance, backs down and drags it into the nest. *Rhopalum (Crabro) abdominale* and *Thyreopus (Crabro) argus* display great skill and precision in slipping into their nest, the former actually diving into her open door-way without stopping at the entrance.

The manner of entering the nest depends somewhat on whether the nest is open or closed when the wasp arrives. In this particular there is great variation in the species as well as in the individuals. *Microbembex* usually closes her nest on leaving it but sometimes leaves it open; with *Bembex texanus* the exact opposite habit prevails. *Ammophila Procera* closes her nest after each visit in cases where she stores more than one caterpillar. *Monedula carolina* leaves her nest open as often as she closes it, *Bembex belfraegi* and *Bembidula* close their nest more often than they leave it open. *Miscophus* and *Hoplisoides* always carefully close their nests before leaving. *Thyreopus*, *Alyson* and all solitary wasps that use mud in their architecture never close their nests on leaving on a hunting expedition; the female *Trypoxylon*, however, leaves the male on guard in her absence. Among the spider-ravishers that capture their prey before digging their nests many carry their spider out of reach of predatory enemies until the nest is ready (Fig. 5).

A given species of wasp will usually confine herself to a particular kind of prey: a bug-catcher will always take bugs, a spider-ravisher never anything but spiders, an *Ammophila* only caterpillars, etc. Sometimes, as in the case of *Priononyx Thomae*, *Alysonmelleus* and *Rhopalum abdominale* and *Thyreopus argus*, the specialization is so complete that a certain species of grasshopper, leaf-hopper or fly is adhered to, all other grasshoppers, leafhoppers or flies being refused. The opposite habit, a universality of insect-food, obtains with *Microbembex*, which carries to her young any insect dead or alive or any part of an insect which she can find and capture (Chap. III.)

Each species of wasp has learned the life habits of its prey and therefore frequents the latter's haunts. *Bembex texanus* and other fly-catchers hover around the droppings of cows and horses and

around these animals themselves; *Bembex belfraegi* makes trees and bushes her hunting grounds; leaf-hopper catchers fly in and out among the grasses in search of food for their young; the cricket-killer *Larra* runs into and out of holes in the ground or under stones; *Microbembex* glides gracefully through the woods satisfied with the first insect or part of an insect that comes to view.

As regards the feeding habits among solitary wasps two types may be recognized: first that in which the growing larva is fed by the mother from day to day until the larval or eating stage has passed and the larva has spun its cocoon and become quiescent; and second, the type in which the store of food is provided once for all, the egg laid among the provisions, the nest closed over the egg and the larva left to its fate.

The Peckhams consider the habit of feeding the larva from day to day as the most primitive. They say: "It may be possible then that all wasps originally fed their young as *Bembex* now does and that while the instinct of storing the whole supply of food once for all was working itself out among solitary wasps, the instincts of life in a true society developed into those of our wasp communities." From this point of view, *Microbembex* on the one hand and the social wasps on the other show the habit in its most primitive form since they not only feed their larvae until these pupate, but they gather almost any kind of insect food they find. The first step in the development among the Digger-wasps would then be the specialization shown in all other wasps of confining themselves to one kind of prey (flies, bugs, caterpillars, as the case may be). In this *Bembex* and some species of *Monedula* are most primitive, since they continue to feed their larvae from day to day. Finally comes the habit which obtains in nearly all solitary wasps of provisioning the nests once for all. This is shown in its highest form in the *Ammophiles* and *Pompilides*, which paralyze the caterpillars and spiders, store them in the nest and lay the egg upon them. In these cases the nest is closed long before the egg is hatched and the mother wasp never sees the larva. There are however, transitional cases between the habits of *Bembex* and that of *Ammophila*. Thus *Monedula carolina*, the big fly catcher, closes her nest several days before the larva spins its cocoon, after first supplying the larva with a sufficient supply of food. The little bug-catcher *Bembidula parata* shows a somewhat greater difference, for while she stores her nest as fast as she can with very small bugs, the work is not finished until

the larva is at least half-grown. Another instance, showing a still greater step in the direction indicated, is shown by an *Ammophila urnaria* described by the Peckhams. This species lays the egg on the first caterpillar brought in and stores the other or others as soon as she can. In one case, the mother wasp on her return with the second caterpillar found a larva a day old feasting on the caterpillar already provided.

It is interesting to note that, parallel with the working out of the instinct to store the nest quickly and close it up over the unhatched egg, runs the development of the stinging instinct, which aims to paralyze the prey to preserve it for the future offspring. Thus *Microbembex*, which is the most generalized in the mode of procuring food, seldom needs to sting her prey, for she nearly always finds it dead. When she stings, it is to kill and from a single observation I judge her to be very awkward in the application of her sting. The five caterpillars I saw her carry into her nest were all dead. The greater part of the caterpillars captured by *Ammophila* or *Odynerus*, wasps that specialize in that kind of prey, are brought into the nest merely paralyzed instead of killed outright.

Bembex tex and other fly-catchers sting their flies to death with a single prolonged sting as I observed in Chap. IV. This suggests the idea that the primary purpose of the sting is to overcome the victim.

Among most of the other solitary wasps the tendency to merely paralyze the victim is more or less perfectly developed. Bugs, grass-hoppers, bees, spiders or caterpillars are sometimes brought in stung to death, but often they live from a few days to many. The nearest approach to perfection is reached in the *Ammophilae*. So nearly perfect is the habit here that Fabre was led to assert that two conditions always obtain with *Ammophila*'s caterpillars and are absolutely essential to the perpetuity of the species: first, that the caterpillar must be sufficiently paralyzed to insure the safety of the egg, yet secondly, it must remain alive sufficiently long to furnish fresh food for the growing larva. Though Fabre has noted a slight variation in the number and order of the stings administered he insists of the necessity of stinging the caterpillar in the middle segments, one of which is to receive the egg, and his observations seem to bear him out. In Chap. II, I have given my own observations on five caterpillars of *Ammophila procera* which fulfilled to a nicety the condition thus laid down by Fabre. In each case the

caterpillar lived long after the egg should have hatched, yet in each case the caterpillar was sufficiently stung in the middle segments to insure the proper quiescence. It must be said, however, that the five caterpillars thus observed are not sufficient to yield conclusive results. In this connection we should listen to the Peckhams, whose opinions, diametrically opposed to those of Fabre on the question of the stinging and other instincts of wasps, yet seem to me to be well established. Fabre argues that the wasp's actions are the result of an automatically perfect instinct which allows no variations. The Peckhams combat this view, holding that, in their study of wasps, the "one preeminent unmistakable and everpresent fact is variability; variability in every particular; in the shape of a nest and in the manner of digging it, in the condition of the nest (whether closed or open) when left temporarily, in the method of stinging the prey, in the manner of carrying the victim, in the way of closing the nest and last, and most important of all, in the condition produced in the victims after stinging, some of them dying long before the larva is ready to begin on them, while others live long past the time at which they would be attacked and destroyed if we had not interfered with the natural course of events. And all this variability, we get from a study of nine wasps and fifteen caterpillars."

Fabre's opinion of the instinct of wasps has long been the prevailing one among naturalists. Romanes depended on Fabre for his information. The question would not have been dreaded by Darwin but welcomed with delight had he been aware of the facts as afterward presented by the Peckhams. The central point from which the influences of the older naturalists were drawn, was the assumption that the larvae must be nourished upon fresh food.

The fact is now, however, fully established that the larva thrives quite as well upon dead as upon living food.

The study of the habits of animals is, indeed, a most fascinating branch of zoological work, and the solitary wasps, though so little studied, are among the most interesting objects of study owing to the great variety of their activities. As to the result to be derived from a study of their habits, the solitary wasps may be expected to contribute no small quota toward the solution of the psychological problems concerning the lower animals.

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5. Spider placed on leaf by *Pompilus marginatus* for safe keeping.
x¹/₂.
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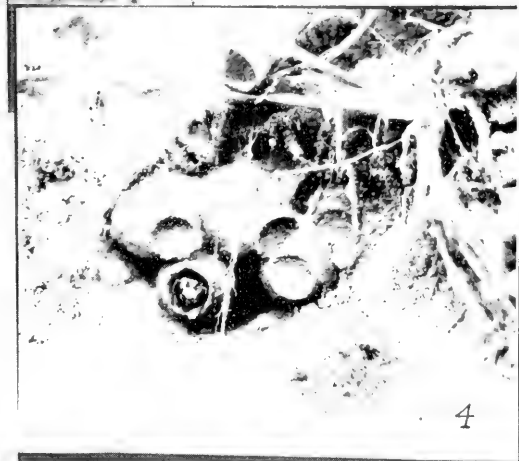
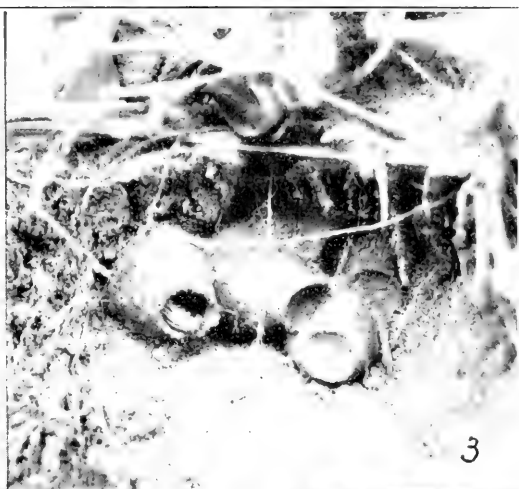
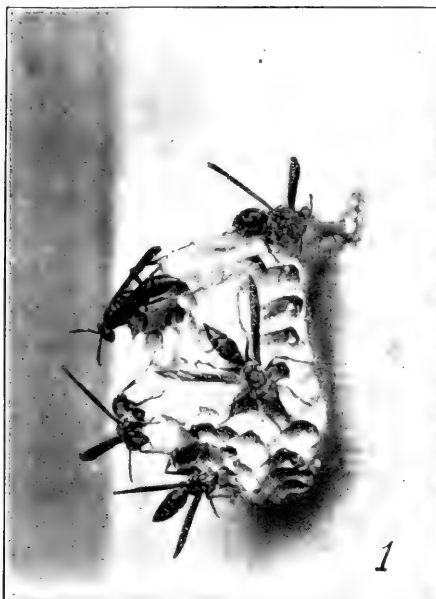


Plate I. Hartman, Solitary Wasps.

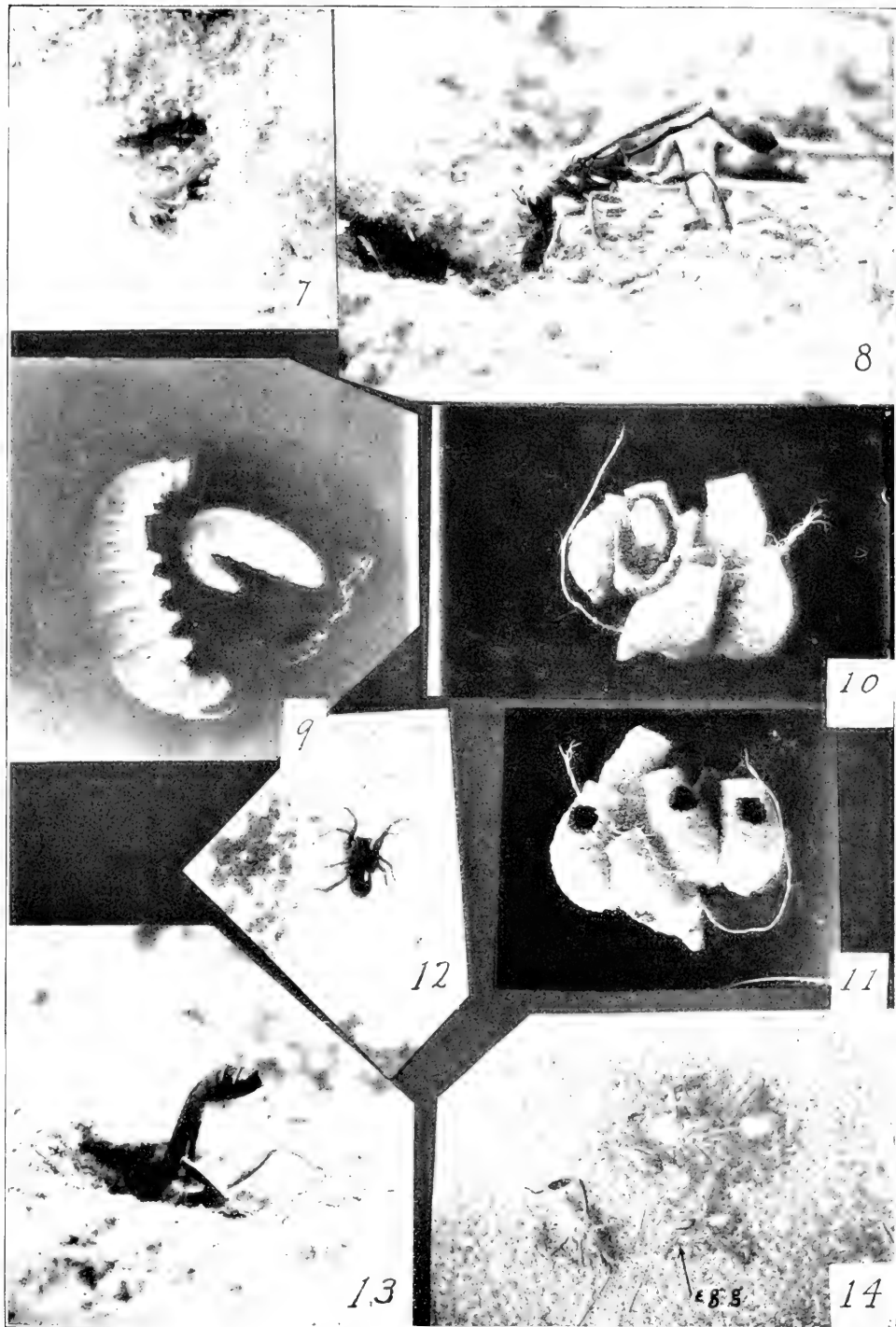
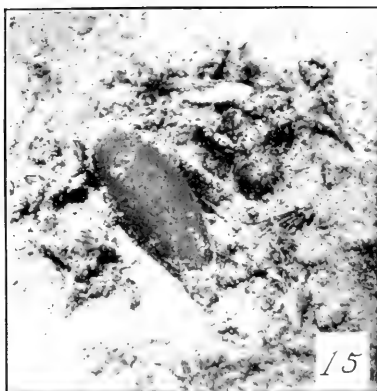


Plate II. Hartman, Solitary Wasps.



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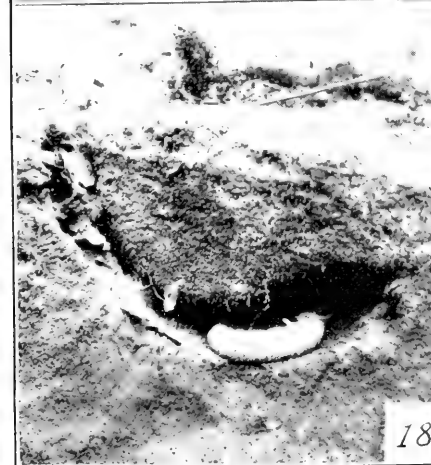
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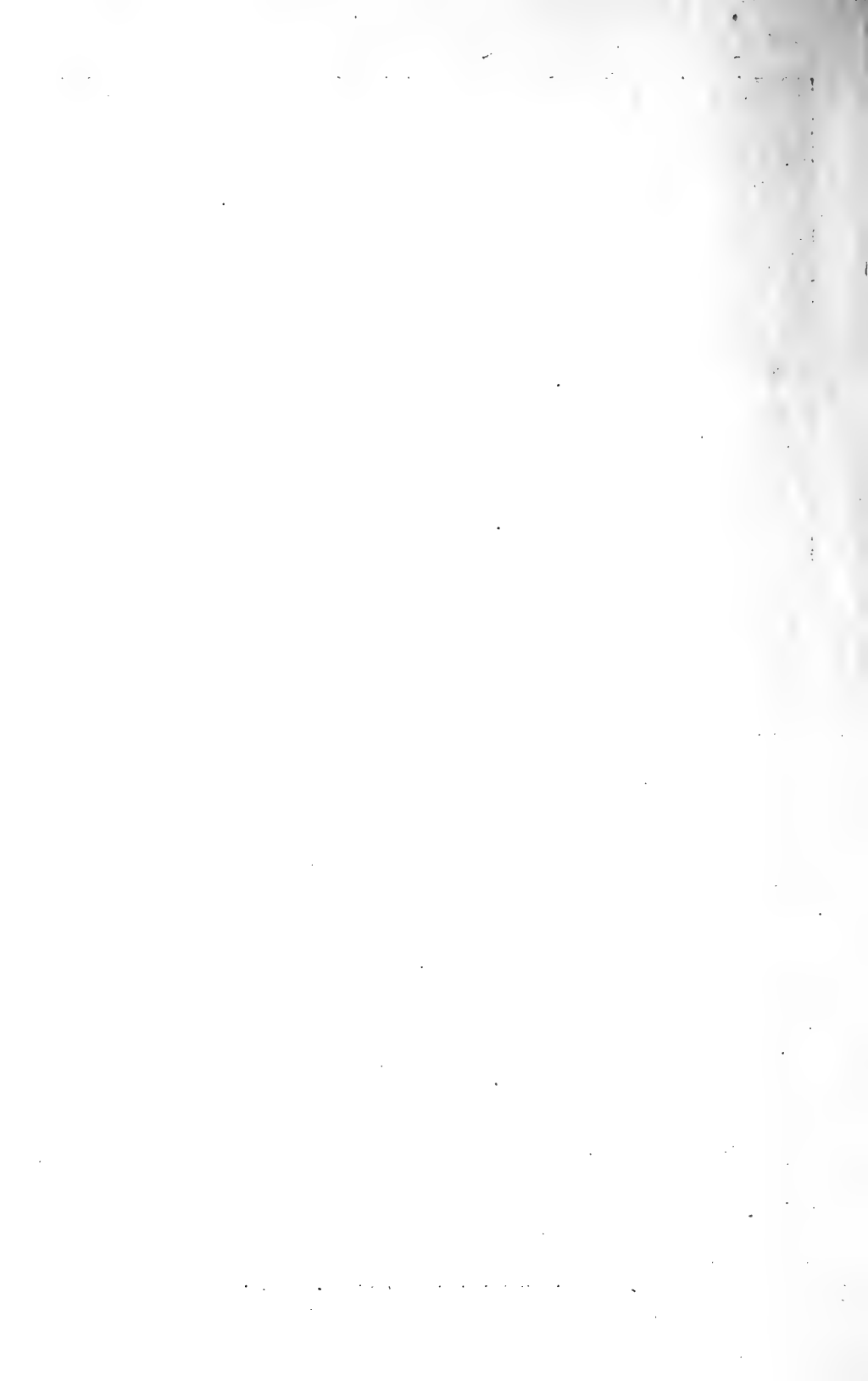


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Plate III. Hartman, Solitary Wasps.



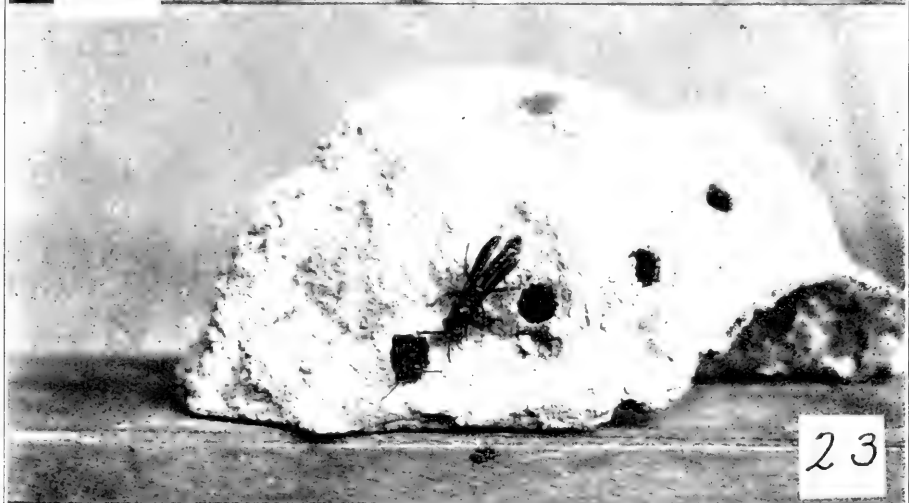
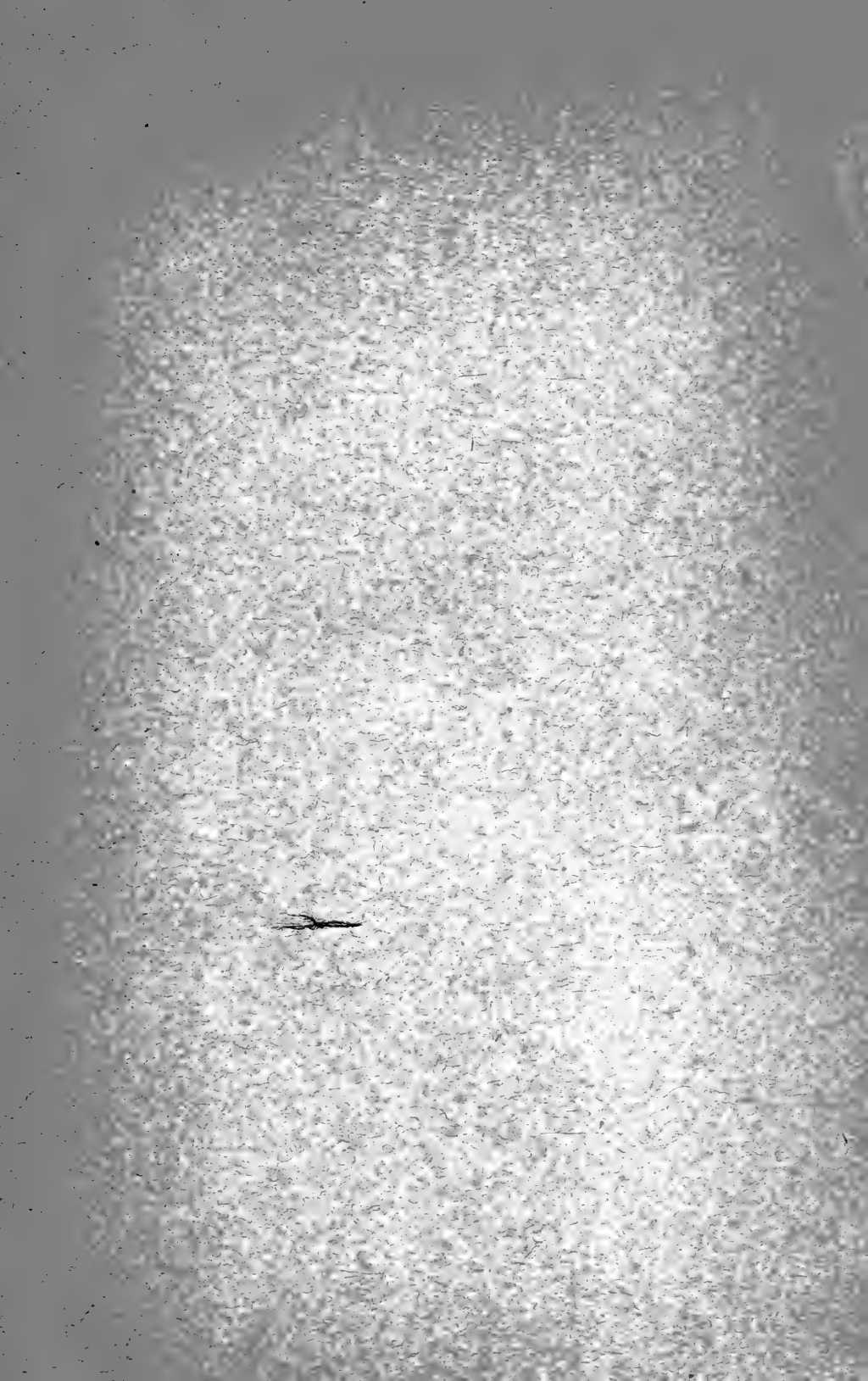


Plate IV. Hartman, Solitary Wasps.

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